# Part 1: Evaluation and Modification of Open Web Steel Joists and Joist Girders

OCTOBER 16, 2024



*Presented by:*

*Bruce F. Brothersen, PE, Vulcraft*

*Walter F. Worthley, Jr., PE, SE*

# Presenters

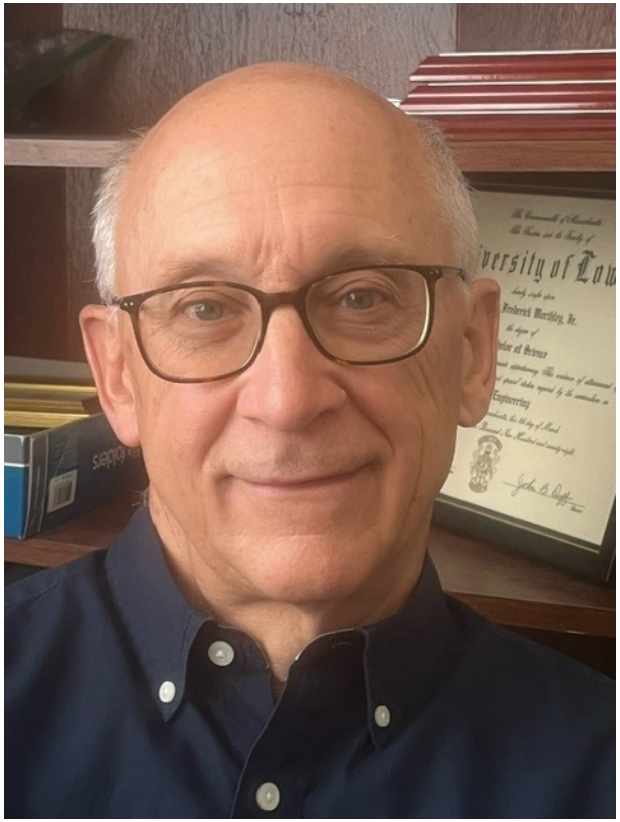
**Bruce F Brothersen PE, SE, Peng**

Senior Innovator - Vulcraft Innovation Services Group

Vulcraft for over 30 years

SJI Education Committee Chairman

# Presenters



## Walt Worthley, PE, SE

Owner/Principle Engineer – SEQ Engineering, LLC.

Chief Engineer for Valley Joist & Deck for 21 years.

SJI Engineering Practice Committee and Education Committee.

# Polling Questions

- Required to earn PDH credits.
- Questions will be asked during the duration of today's presentation.
- The question will appear within the polling section of your GoToWebinar Control Panel to respond.
- Please be sure that your pop-up blocker is disabled. If you're in full-screen mode, the GoToWebinar polling widget will appear behind the slides. You'll need to exit the full screen to be able to access it.

# Disclaimer

The information presented herein is designed to be used by licensed professional engineers and architects who are competent to make a professional assessment of its accuracy, suitability and applicability. The information presented herein has been developed by the Steel Joist Institute and is produced in accordance with recognized engineering principles. The SJI and its committees have made a concerted effort to present accurate, reliable, and useful information on the design of steel joists and joist girders. The presentation of the material contained herein is not intended as a representation or warranty on the part of the Steel Joist Institute. Any person making use of this information does so at one's own risk and assumes all liability arising from such use.

# Webinar Description

This is part one of a two-part series. Part one will discuss and demonstrate the methods to first evaluate existing open web steel joists and Joist Girders for revised loading conditions. This webinar parallels the Steel Joist Institute publication, Technical Digest No. 12 “Evaluation and Modification of Open Web Steel Joists and Joist Girders.”

# Learning Objectives

- Identify the key characteristics of in-place joists.
- Learn how to determine who the original manufacturer was and whether they can provide any additional documentation.
- Learn how to verify the original design loads and evaluate the joist for the new loads.
- Discuss procedures, as part of the evaluation, to identify the joist components and connections that are inadequate.

# Outline

- Introduce the revised SJI Technical Digest 12.
- Introduce the new SJI design tool for the modification of joists and/or Joist Girders.
- Identify the key characteristics of in place joists.
- Identify methods to determine who the original manufacturer was and whether they can provide any additional documentation.
- Verify the original design loads and evaluate the joist and Joist girder for the new loads.
- As part of the evaluation, procedures will be discussed to identify the adequacy of the joist and/or Joist Girder components and connections.

# Introduction

Evaluation and Modification of joists are required for four main reasons:

- Design changes (new loading requirements)
- Field deviations – Dimensional changes
- Damage to the joists - both intended and unintended.
- Other changes not contemplated in the original design (plane crash into roof)

# Introduction

- Commercial manufacturing of open web steel joists began in 1923
- The Steel Joist Institute was formed in 1928
  - Open Web Steel Joist use has continued to grow.
  - There are millions of Open Web Steel Joists in service.
- Changing specs and materials.

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# That is the First Question

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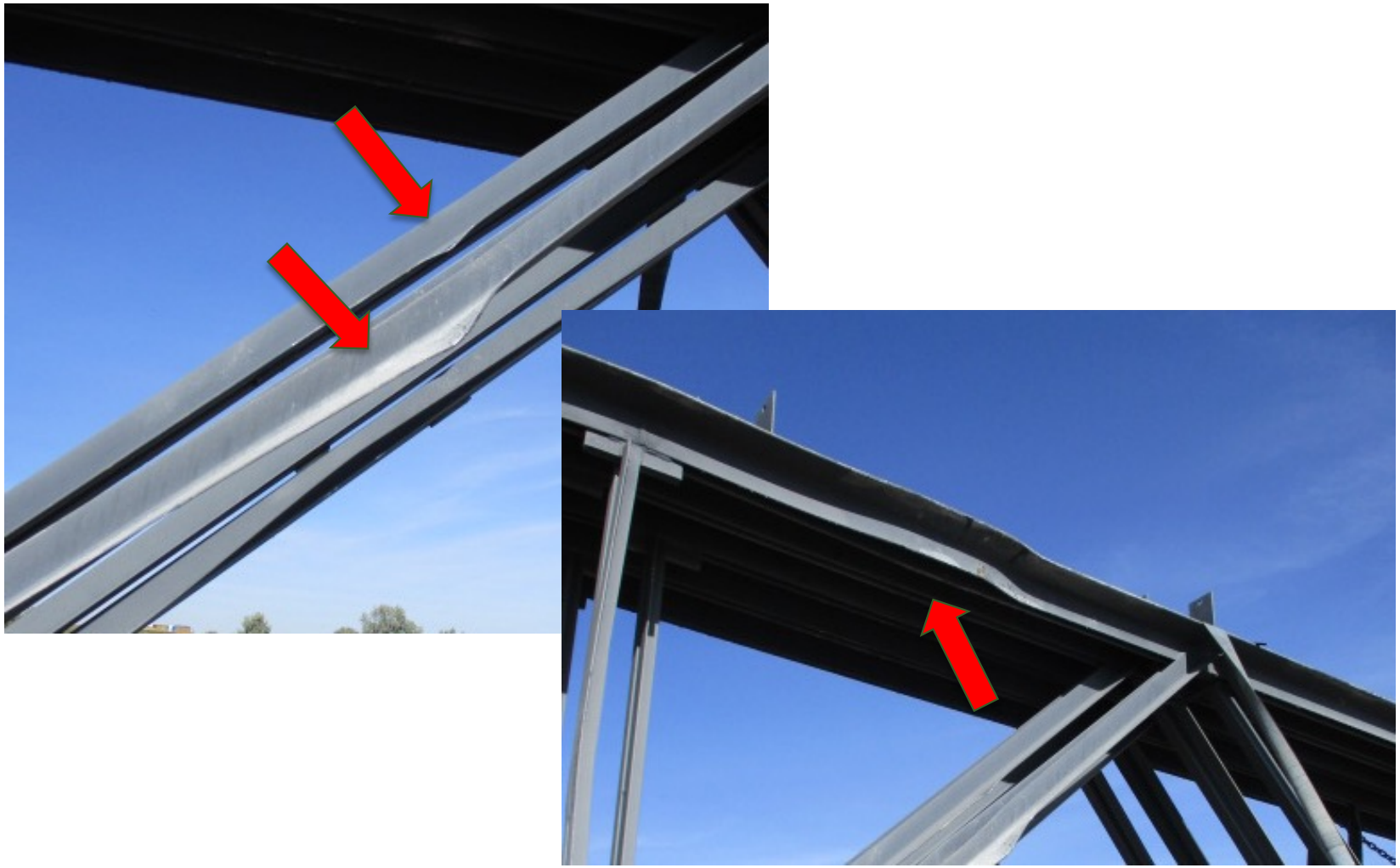
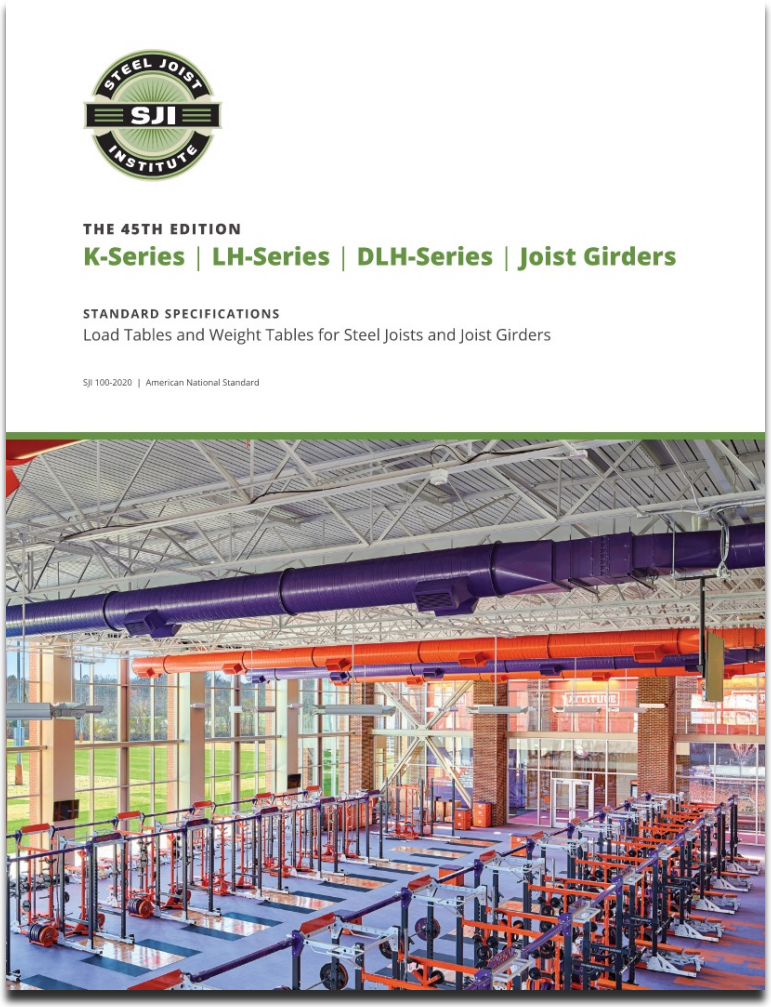


# To Fix or Not to Fix
# That is the First Question

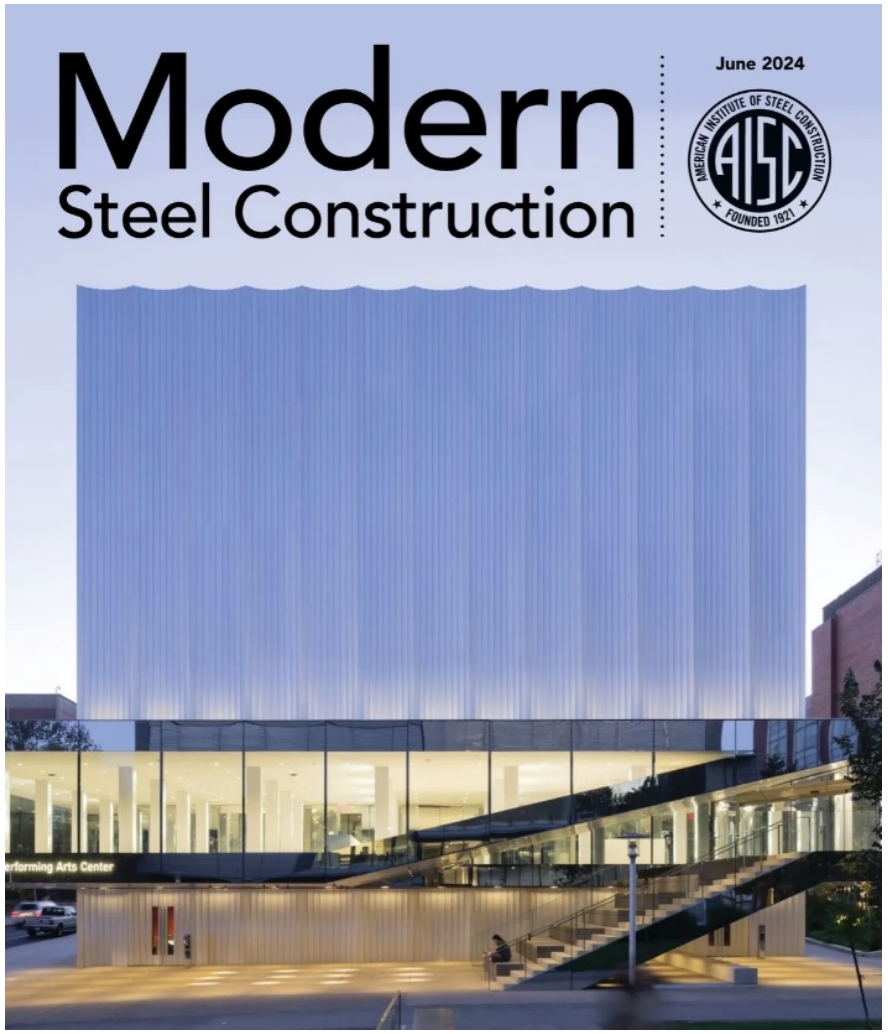
**Each situation is different and needs to be evaluated independently.**

# 2020 SJI Specification

- Combined Standard Specifications - 45th edition
- K, KCS, LH, DLH, G
- Load tables
  - K-Series Load Tables
  - KCS Joists
  - LH- and DLH-Series Load Tables (Newly Expanded DLH-Series)
  - Joist Girder Weight Tables
- Code of Standard Practice
- Order from: www.steeljoist.org
  **Free download – Pay for hardcopy**



# June 2024 – MSC




steelwise

## Joist Journey

BY BRUCE BROTHERSEN, PE, AND KEN CHARLES

Evaluating open web steel joists for potential modification is both an art and a science.

**OPEN WEB STEEL JOISTS** and joist girders are key components of steel construction.

There are millions of open web steel joists and joist girders in roofs and floors of thousands of buildings throughout the United States, Mexico, and Canada. As building needs change, the joists will have new requirements as well. Additionally, as steel making and steel grades have evolved, as the specifications of open web steel joists progressively changed.

Evaluating and determining if a joist needs modification is a valuable skill that's an art and a science. The art is easier than most might think, and there are tools to assist with the science. The Steel Joist Institute (SJI), formed in 1928, has developed Technical Digest 12, *Evaluation and Modification of Open Web Steel Joist and Joist Girders*, which explains methods and techniques to evaluate and modify existing joists.

Open web steel joists have five main components. In simple terms, the chords are axial force carrying components on the top and bottom of the overall member. These members are usually horizontal, with some exceptions. The webs are members connecting the chords that transfer the shear forces. Bearing seats are the means on both ends of the joists to distribute the forces to the supporting structure and are connected to the supporting structure by welding or bolting. Welding connects all joist components. Bridging is the method for laterally bracing the chords during erection and service.

Manufacturers will not have the exact same method for building joists, but even with minor differences, open web products are simple and amazingly strong.

Each project is different, and the evaluator will need to gather as much information as possible on the existing structure. Sometimes, fact finding is easy. Other times, it's arduous and time-consuming.

The older the building, the less likely information such as shop bills or drawings will be available. On projects completed within the last 20 years, it's likely the joist manufacturer can be contacted, and it may have all the necessary information.

Older projects with limited available information make joist engineering an art and less exact. The art is careful approximation based on available data and facts to determine enough information to employ the more formulaic and precise science.

Evaluation questions to ask are listed in the Joist Investigation Form (Figure 1), found on the website or in Appendix A of Technical Digest 12. They're a strong basis for creating a guideline or checklist for information gathering.

With enough information, you can zero in on which specification was used for the joist design. You can also make some safe assumptions on the loading. Just by identifying the seat depth, you can usually assume the joist is either a K-series (2½ in.) or LH-Series (5 in.).

Part of the art of joist design is understanding most manufacturers do not purchase angle stock that would match angle sizes in the 16th Edition *Steel Construction Manual* (current and previous editions can be found at aisc.org/manuals). In fact, for joist use, you would likely find a 2 in. by 2 in. angle in seven different leg thicknesses, ranging from .137 in. to ¼ in.

To practice the art, take a micrometer thickness reading on the bottom chord. Determine the maximum tensile force by multiplying the bottom chord cross sectional area by $0.6F_y$. From there, based on

What year was the building constructed (or approximate age of the structure)? _____
Who was the joist manufacturer? _____
Is there a tag on the joist? ○ No ○ Yes Provide tag information _____
What type of trusses are the joists? ○ Warren ○ Modified Warren ○ Pratt ○ Other _____
What were the joists used for? ○ Roof loading ○ Floor loading
What type of bridging is used? ○ Horizontal ○ Diagonal
What is the joist span or length of joist? _____ What is the joist spacing? _____
What is the interior panel point spacing? _____ What is the joist depth? _____
What is the height of the joist seat? ○ 2½" ○ 5" ○ Other _____
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○ 1 Round Diagonal web diameter _____
○ Other (provide sketch)
How were these measurements obtained? ○ Tape ○ Micrometer ○ Caliper ○ Other _____

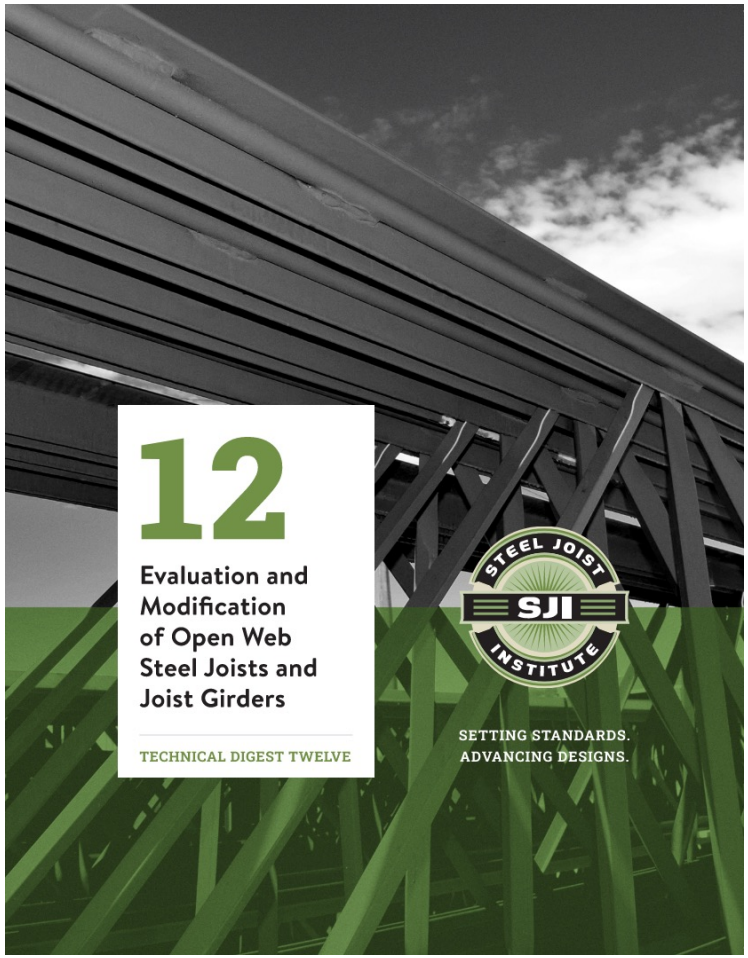
Fig. 1.

# New Resources Available

- Revised SJI Technical Digest No. 12
  - Present procedures
  - Suggest details for modification or strengthening
- SJI design tool for the reinforcement of the joist and joist girders.
- Evaluation and Modification of Open-Web Steel Joists and Joist Girders webinars and On Demand Webinars.

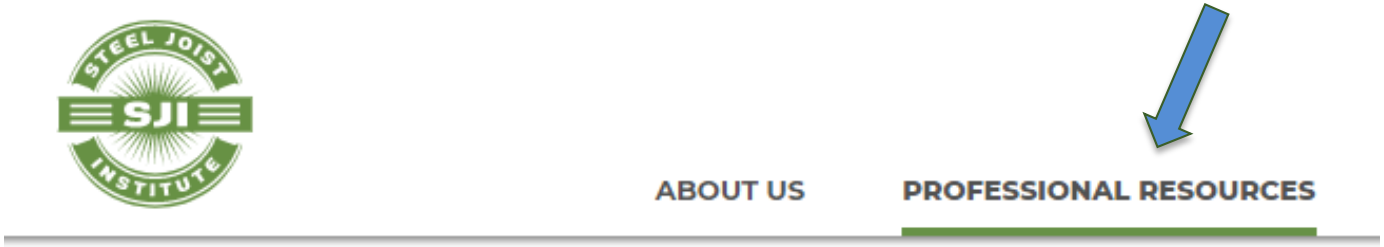
# SJI Technical Digest No. 12

- Evaluation and Modification of Open-Web Steel Joists and Joist Girders
- Price: $40
- Order from: www.steeljoist.org

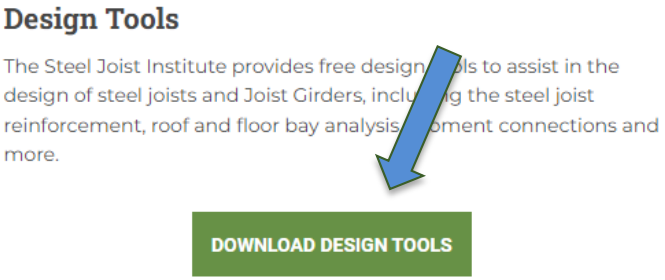


# Joist and Joist Girder Reinforcement Tool

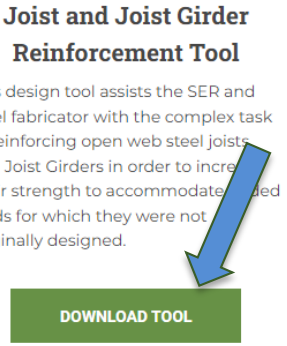
SJI homepage
Click Professional Resources




Professional Resources Tab
Click Download Design Tools




Click Download Tool



# SJI Technical Digest No. 12

Background

Glossary

| | |
|---|---|
| Chapter 1 | Evaluations of Existing Joist Strength |
| Chapter 2 | Methods of Supporting Additional Load |
| Chapter 3 | Design Approaches For Strengthening Joists |
| Chapter 4 | Design Approaches For Modifying Joists - Shortening And Lengthening |
| Chapter 5 | Other Considerations |
| Chapter 6 | Modification Instructions And Summary |

References

| | |
|---|---|
| Appendix A | Joist Investigation Form |
| Appendix B | Equal Leg Angle Properties |

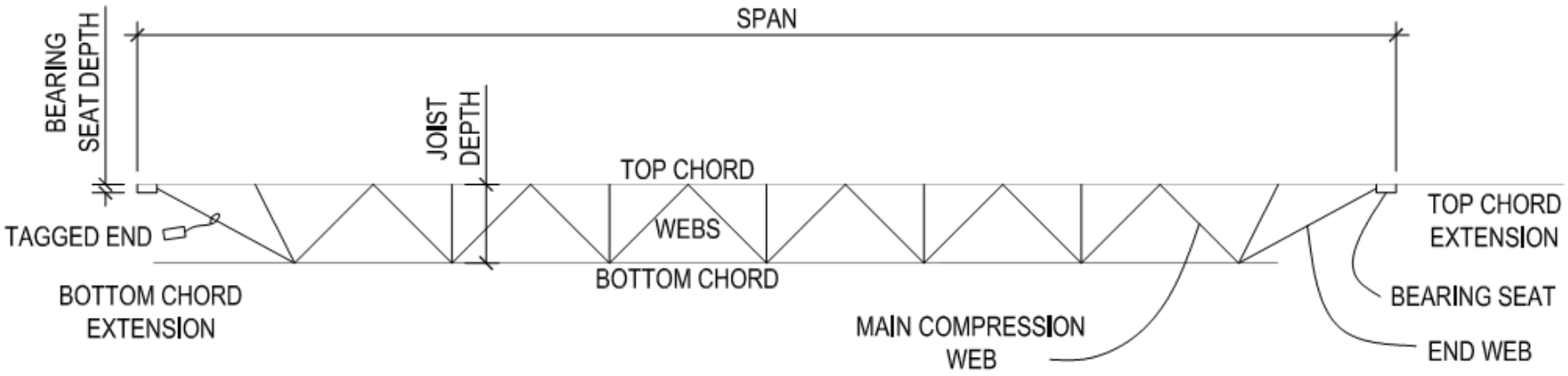
# Glossary of Terms

- Allowable Strength Design (ASD)
- Allowable Strength
- Available Strength
- Bearing
- Bridging
- Buckling
- Buckling Strength
- Camber
- Chords
- Cold-Formed Steel Structural Member
- Composite Section
- Connection
- Deck
- Design Load
- Design Strength
- End Diagonal or Web
- End Welds
- Existing Member
- Filler
- Joint
- Joist
- Joist Girder

# Glossary of Terms

- Load
- LRFD (Load and Resistance Factor Design)
- Material
- Nominal Strength
- Preload Force
- Reinforcing Member
- Required Strength
- Resistance Factor, Φ
- Safety Factor, Ω
- Slenderness Ratio
- Span
- Specified Minimum Yield Stress
- Specifying Professional
- Splice
- Stability
- Standard Specifications
- Structural Analysis
- Tagged End
- Webs
- Yield Point
- Yield Strength
- Yield Stress

# Glossary of Terms



# Evaluation of Existing Joist and/or Joist Girders

- What information do I have?
- What information do I need?

# Evaluation of Existing Joist and/or Joist Girders

Ask for the information that you have not been told.

- What is condition of existing joist?
- What design or as-built information is available?
- What materials were used to build the joist?
- Pictures?

# Chapter 1
# Evaluation of Existing Joist Strength

Determine capacity of existing joist system

- As-built design of joists
- Existing joists possibly over specified
- Building usage may have changed
- Have joists been damaged

# As – Built Design of Joists

How to determine

- Original contract structural documents
- Final joist erection drawings
- Year job was constructed
- Joist manufacturers identification tag
- Field investigation and measurements

# Evaluation of Existing Joist for Revised Loads

BEST OPTION:

- Find construction documents
  - Contract drawings and/or joist erection plan
- Onsite Investigation
  - Joist tag
  - Determine the specifications and material the existing joist were designed and built to.

# Evaluation of Existing Joist for Revised Loads

BEST OPTION:

- Contact Joist Manufacturer – Best First Option
  - See if calculations are available. In most cases the manufacturer will have a minimal cost to locate, copy and send information on old projects.
- In General:
  - Pre 2000 – No Records
  - Post 2000 – records are available from the companies still in operation.

# Evaluation of Existing Joist for Revised Loads

SECOND OPTION:

- Find construction documents
  - No Contract drawings and/or joist erection plan
- Onsite Investigation
  - No Joist tag - then document joist in question
- Project Name and Address (Seems to change)
- Complete the Joist Investigation Form
- Contact SJI for assistance

# Joist Identification Tag

Joist tag is normally found on the end web.

# Joist Identification Tag

The tag is intended for erection purposes but is key to evaluation.

**Joist tag information**

- Joist manufacturer's name
- Joist manufacturer's job number (74-8-0124)
- Erection mark number (J1 or G100)

# Joist Identification Tag

Some manufacturers are now using plastic tags as shown here:

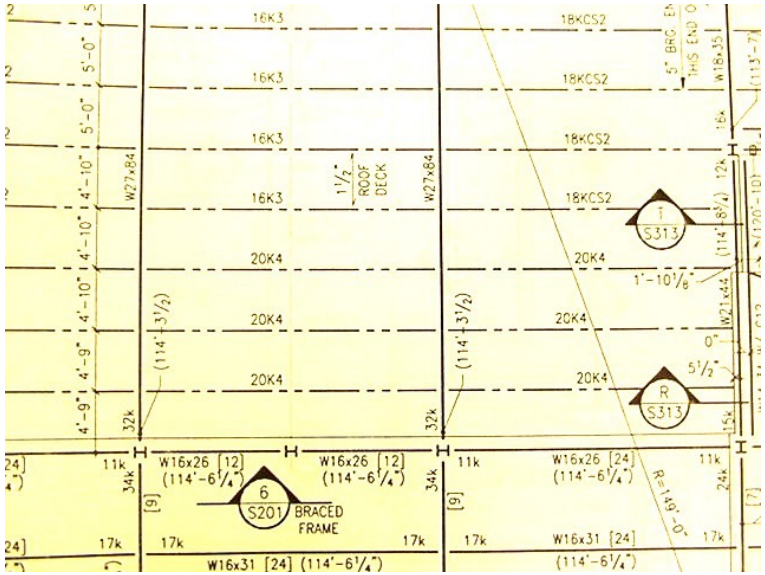
**Joist tag information**

- Joist manufacturer's name
- Joist manufacturer's job numbe & sequence (2F00735-RED)
- Erection mark number (J21)

# Joist Drawings

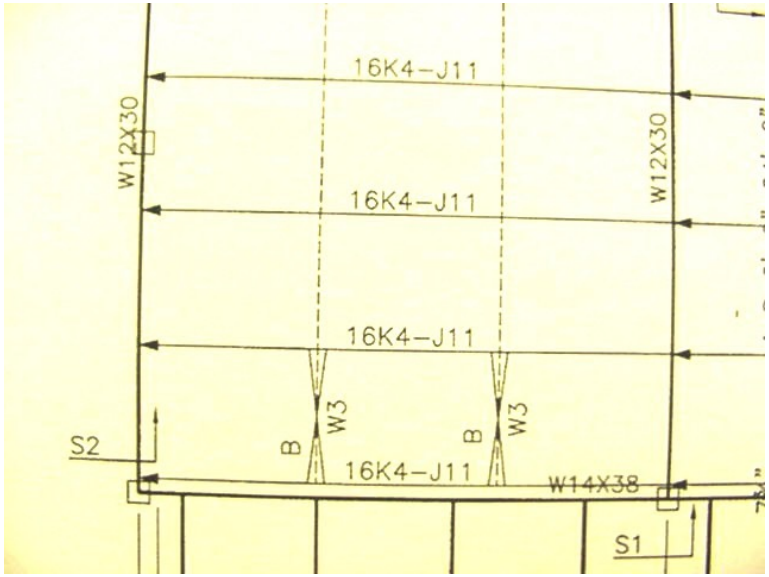
## Structural Drawing

- Designation
- Joist Spacing




## Erection Drawing

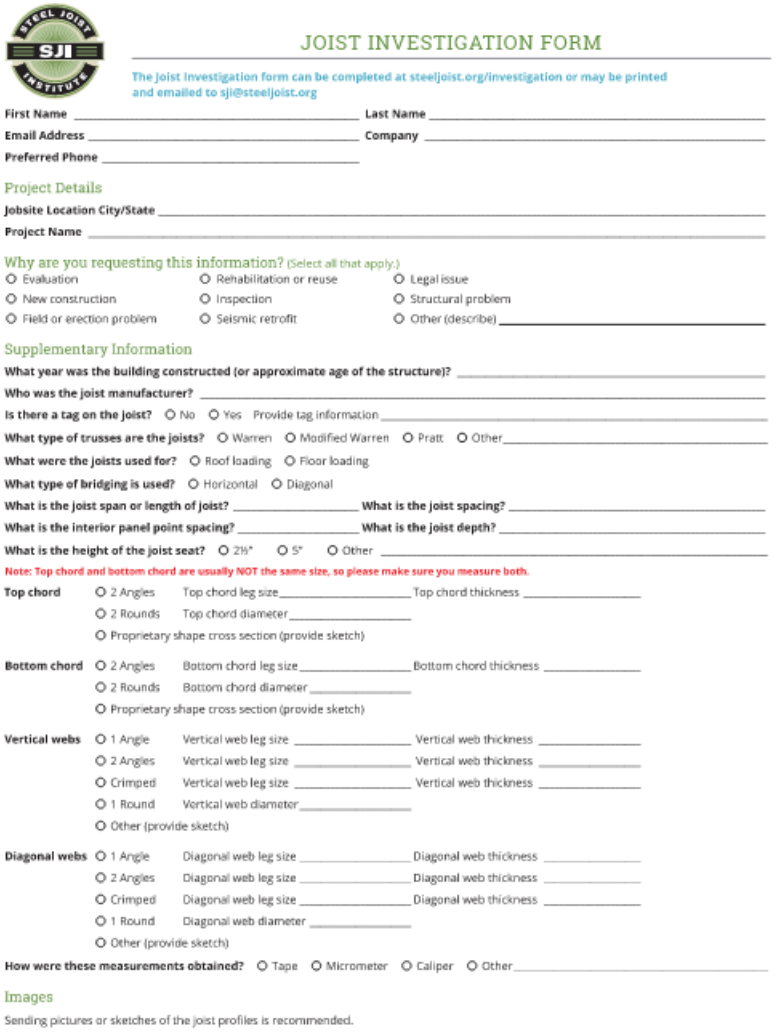
- Designation
- Joist Spacing
- Mark Number



# Joist Investigation Form

Steel Joist Institute assistance

- Fill out the form online
- Download from SJI website
  - www.steeljoist.org
- Return to SJI office or manufacturer for assistance
- Appendix A of TD 12



JOIST INVESTIGATION FORM

The joist investigation form can be completed at steeljoist.org/investigation or may be printed and emailed to sji@steeljoist.org

**First Name** _____ **Last Name** _____

**Email Address** _____ **Company** _____

**Preferred Phone** _____

Project Details

**Jobsite Location City/State** _____

**Project Name** _____

Why are you requesting this information? (Select all that apply.)

○ Evaluation ○ Rehabilitation or reuse ○ Legal issue
○ New construction ○ Inspection ○ Structural problem
○ Field or erection problem ○ Seismic retrofit ○ Other (describe) _____

Supplementary Information

**What year was the building constructed (or approximate age of the structure)?** _____

**Who was the joist manufacturer?** _____

**Is there a tag on the joist?** ○ No ○ Yes Provide tag information _____

**What type of trusses are the joists?** ○ Warren ○ Modified Warren ○ Pratt ○ Other _____

**What were the joists used for?** ○ Roof loading ○ Floor loading

**What type of bridging is used?** ○ Horizontal ○ Diagonal

**What is the joist span or length of joist?** _____ **What is the joist spacing?** _____

**What is the interior panel point spacing?** _____ **What is the joist depth?** _____

**What is the height of the joist seat?** ○ 2½" ○ 5" ○ Other _____

**Note: Top chord and bottom chord are usually NOT the same size, so please make sure you measure both.**

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○ Other (provide sketch)

**How were these measurements obtained?** ○ Tape ○ Micrometer ○ Caliper ○ Other _____

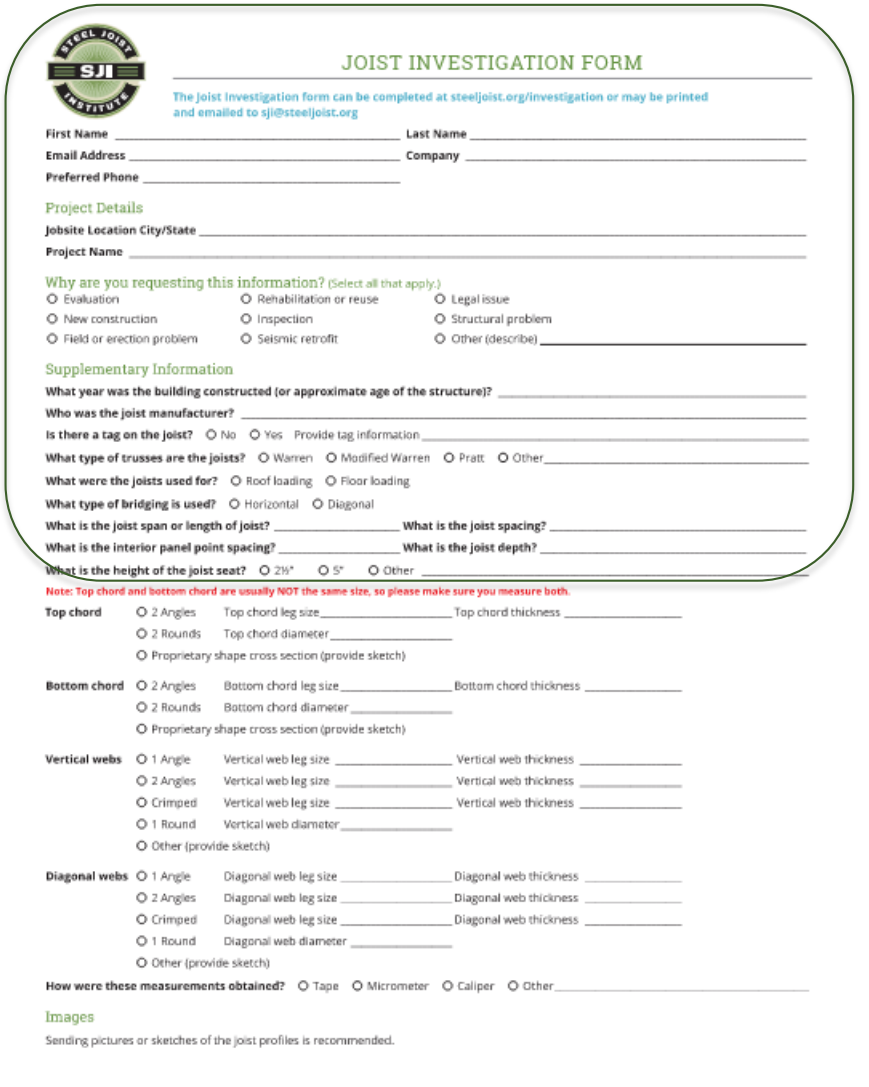
Images

Sending pictures or sketches of the joist profiles is recommended.

# Joist Investigation Form

The form is a good checklist for the known information and what is needed.

All of the information on the top part of the form should be completed to see if as-built information is available.



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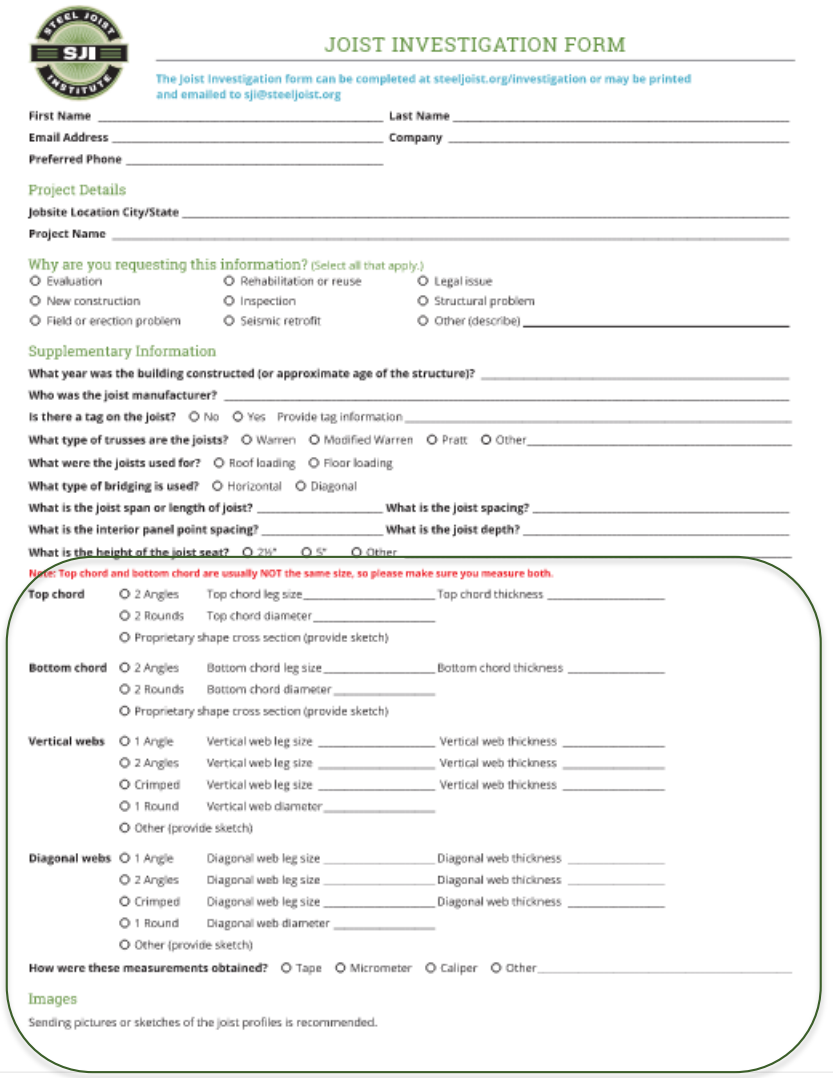
# Joist Investigation Form

If As-Built information is not available, the lower portion of the form should be completed.



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# Field Investigation

Helpful and required information

- Loading on the joists
- Information from the joist tags
- Joist configuration
- Joist span
- Joist spacing
- Joist depth or height
- Bearing condition
  - Underslung or Bottom Bearing

# 90 Year Steel Joist Manual

- Specifications from 1928 to 2018

- Load Tables from 1928 to 2018

# 90 Year Steel Joist Manual

## INVESTIGATION OF STEEL JOISTS IN EXISTING BUILDINGS

### I. General

First and foremost, the investigating engineer, in performing his tasks, should continually be aware of one principal consideration: *the determinations he makes affect the safety of the human beings who occupy the buildings he is investigating*.

Secondly, the task of investigating steel joists in existing buildings is difficult, at best. Personal time, effort, and patience are all required to conduct a proper study.

Thirdly, the investigating engineer should scrupulously observe the following rules:

1) Make as few *assumptions* as possible.
2) Verify by *actual observation and physical measurements* all data whenever possible.
3) Consciously look for *unusual and/or dangerous job site conditions* not specified, shown, or recorded in any documentation.
4) Double check all data.

# Polling Question #1

What information is included on the joist tag?

A. Manufacturer Name

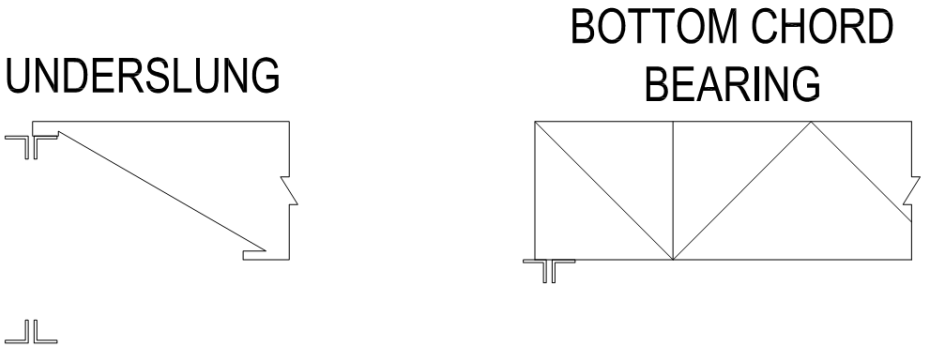
B. Job Number

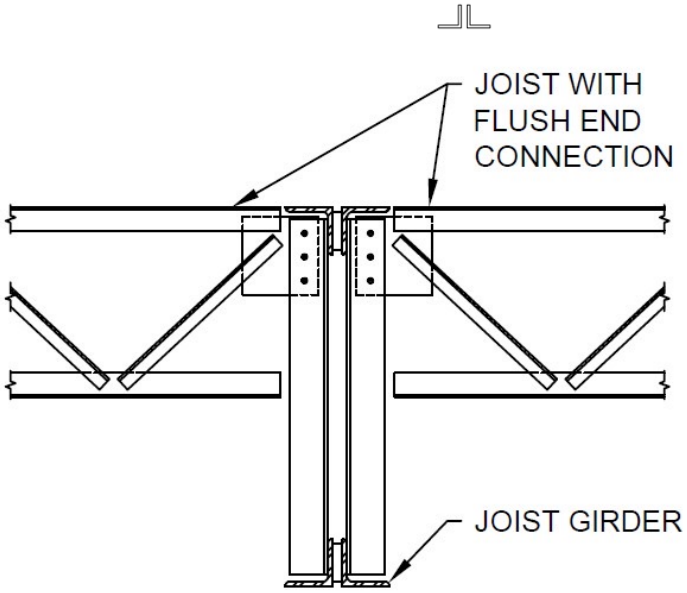
C. Mark Number

D. Joist Designation

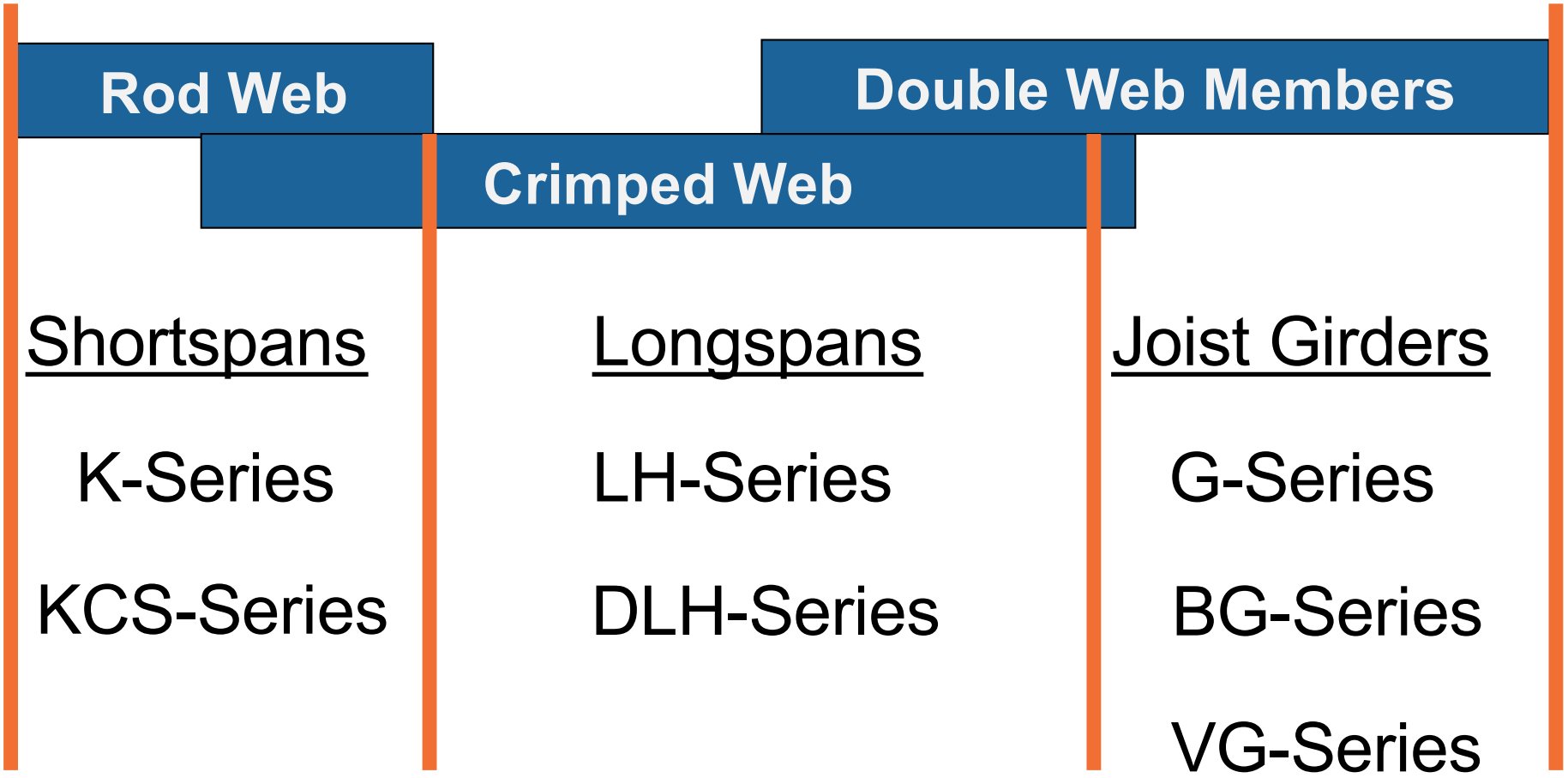
E. A, B and C

# Bearing Condition



# Comparison of SJI Specification Types



# Type of Web Members

## Rod webs

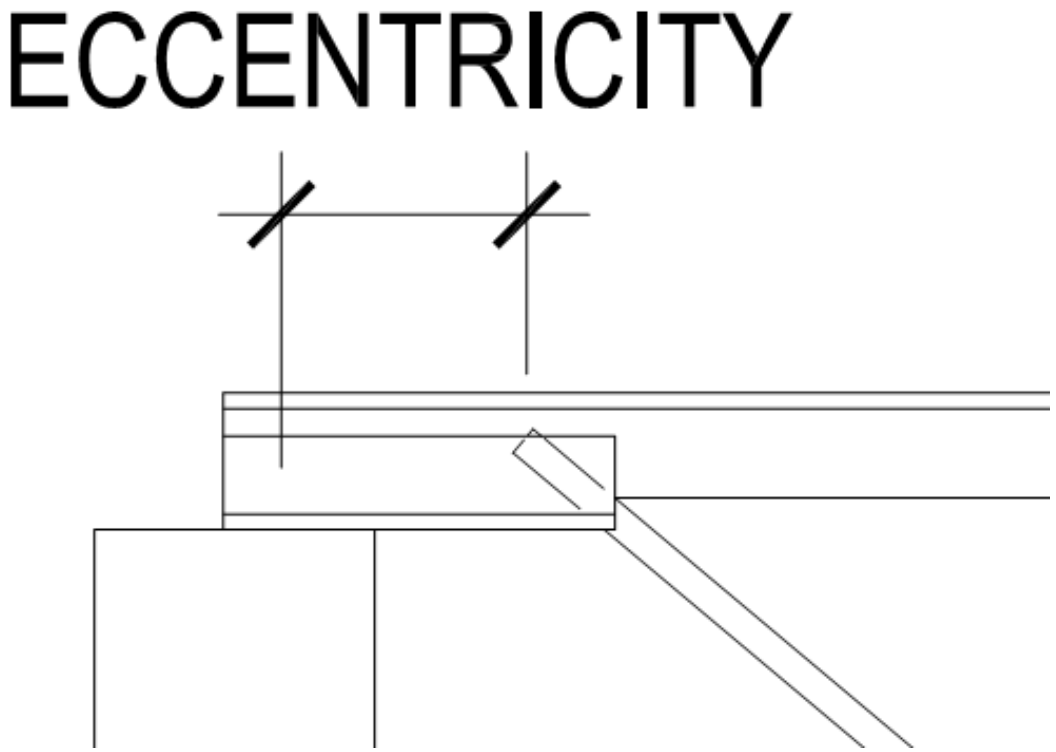
# Type of Web Members

## Crimped angle webs

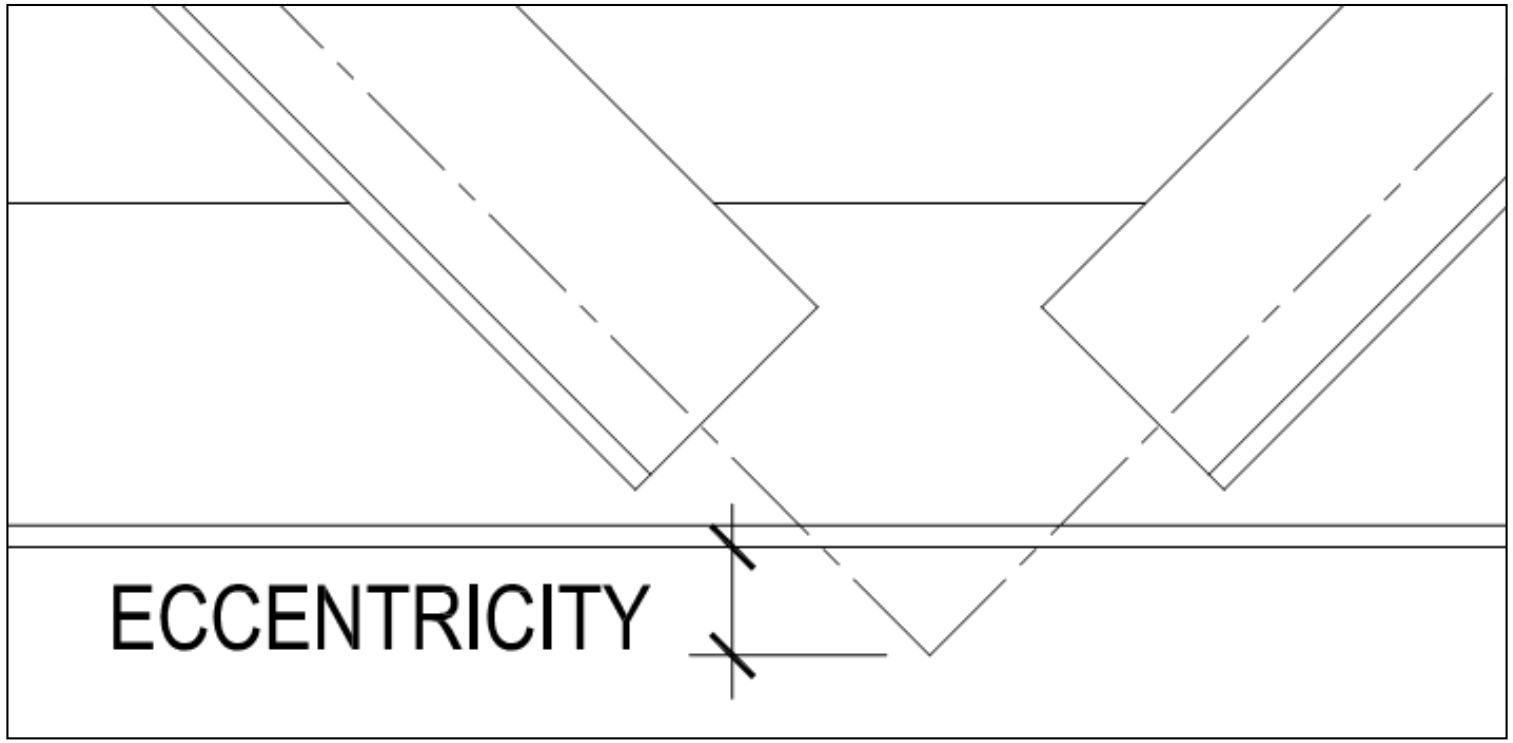
# Type of Web Members

Angles welded to the outside of chords

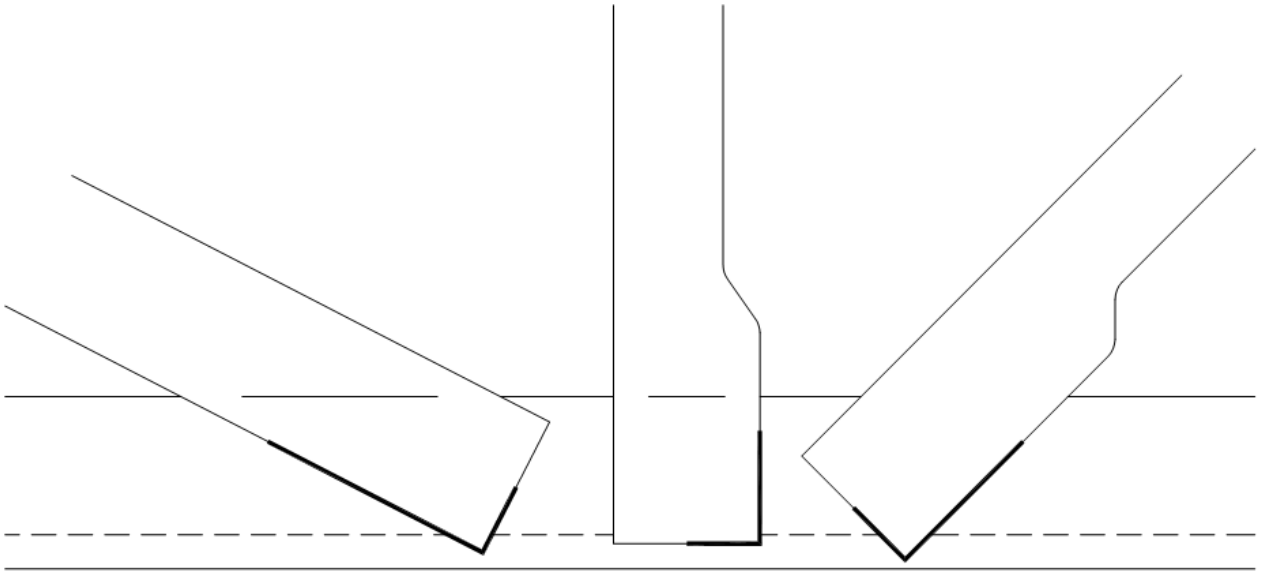
# Bearing Eccentricity



# Web Eccentricity



# Weld Locations Between the Chords



# Welded Connections

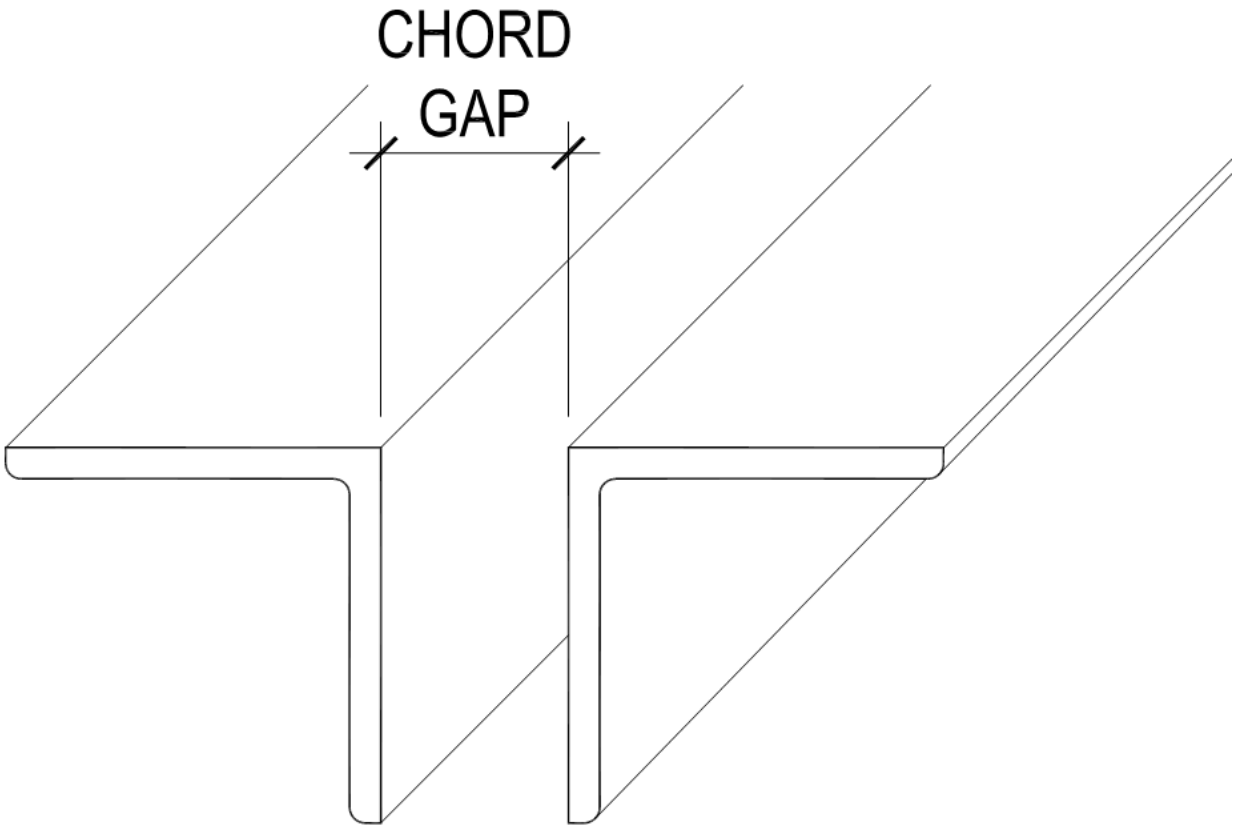
- Weld Sizes and Lengths need to be checked if the forces in the welded members increase.
- Welds are designed for the design force in web, or 50% of the overall member strength not the overall strength of the member.
- Paint may also need to be removed.

# Field Investigation

Type of chord members

- Double angles
  - Separation distance
  - Fillers or ties
- Cold-formed sections
- Rods
- Chord Splices

# Type of Chord Members

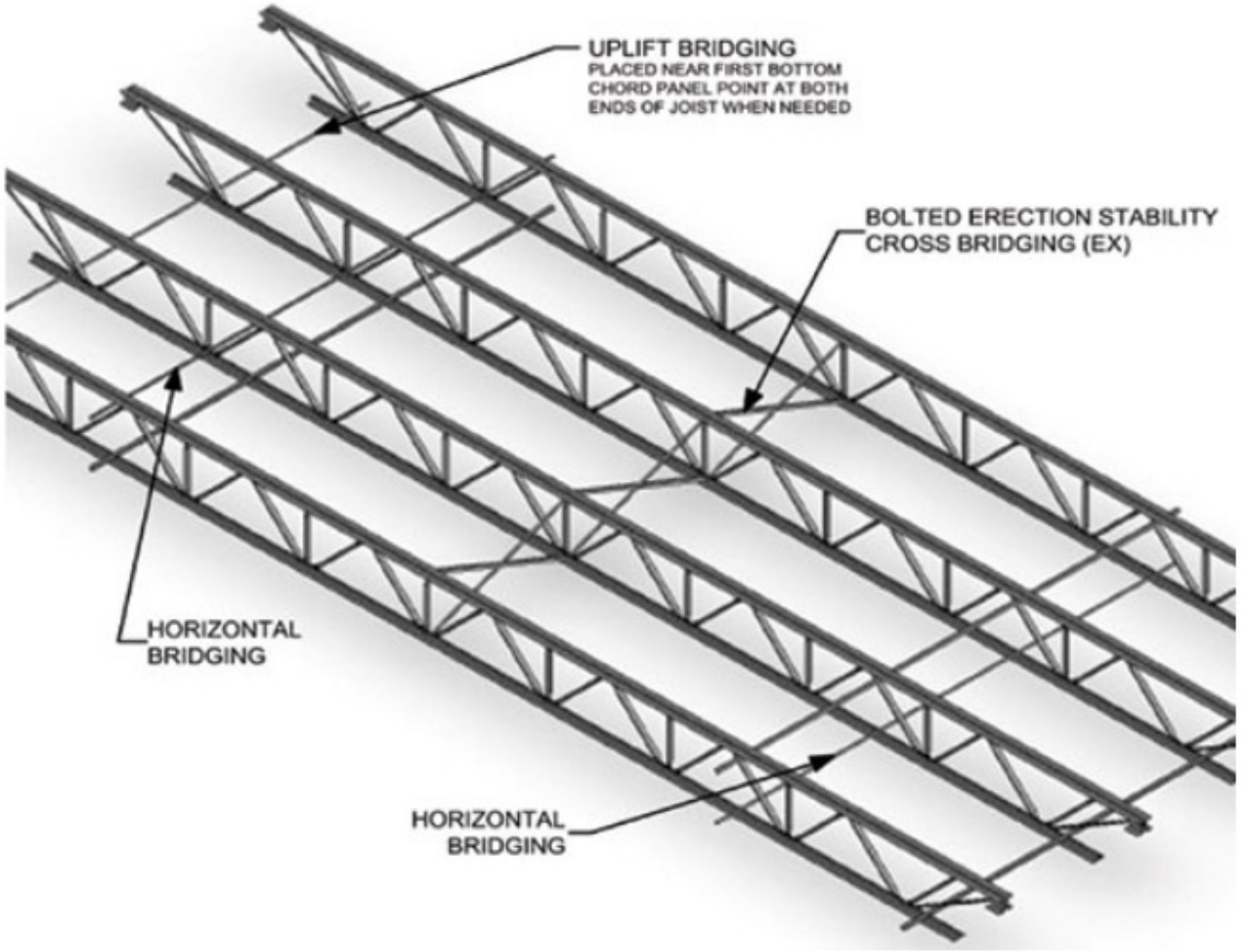


# Field Investigation

Other items to note

- Type of Bridging and Locations
- Quality of bridging connections
- Anchorage of bridging (to structure)
- Interferences (which could affect joist reinforcing)
- Coupon samples to determine yield strength
- Condition of joists and existing deck

# Types of Bridging



# Field Investigation

Where to take a coupon sample

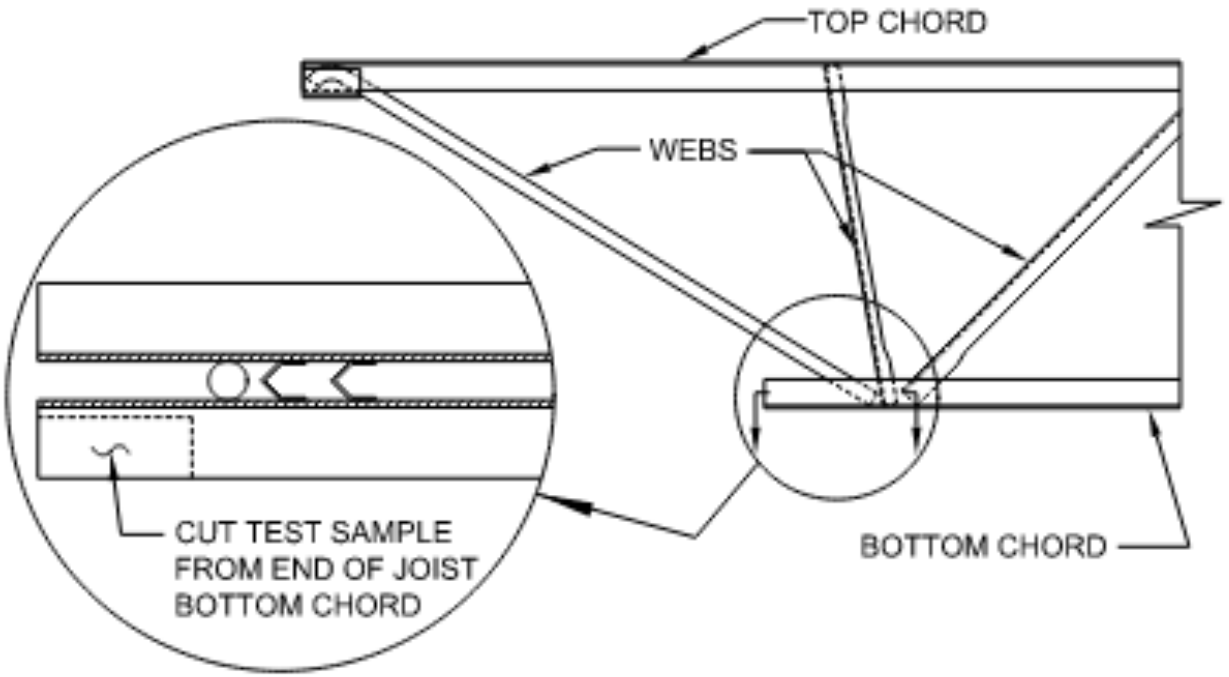



**Figure 1.12**
**Bottom Chord Coupons**

# Joist Chord Damage During Handling

# Joist Damage During Handling

# Joist TC Damage During Construction

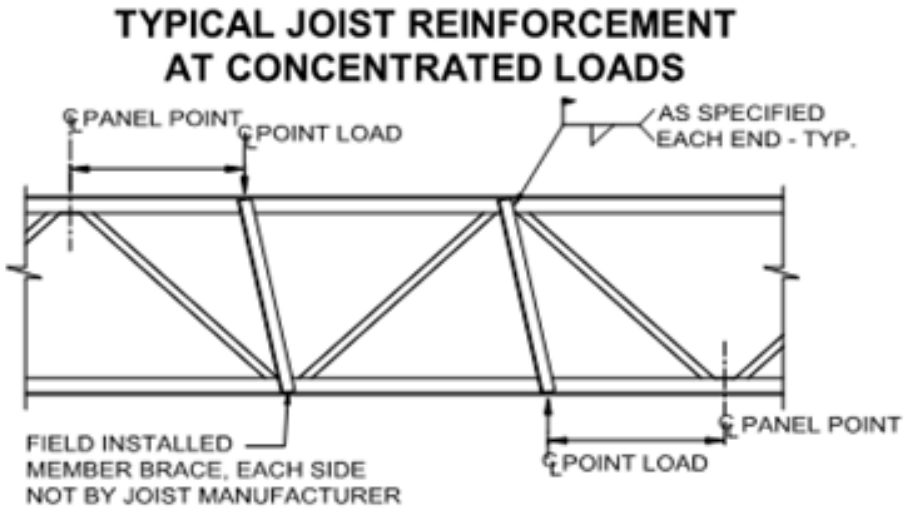
# Joist TC Damaged During Construction

# Methods to Reduce the Need for Minor Repairs

- 100 pound rule
- Add Loads
- Bend-Check Loads
- KCS joists

# 100 Pound Rule

Page 15, 45th Edition of the SJI Spec




Although standard K-Series, including KCS joists, and standard LH-Series and DLH-Series joists are designed specifically to support uniformly distributed loads applied to the top chord, research conducted by the Steel Joist Institute, using second-order inelastic analysis, has demonstrated that the localized accumulation of uniform design loads of up to 100 pounds within any top or bottom chord panel has a negligible effect on the overall performance of the joist, provided that the load is applied to both chord angles in a manner which does not induce torsion on the chords.

→ Concentrated loads in excess of 100 pounds or which do not meet the criteria outlined above, must be applied at joist panel points, or field strut members must be utilized as shown in the detail above.

# Methods to Reduce the Need for Minor Repairs

- 100 pound rule
- Add Loads and Bend Check Loads

https://steeljoist.org/resources/add-loads-and-bend-check-loads/

- KCS joists

# Specifying the Loads

Page 184, 45th edition of the SJI Spec

**Option 3**: For additional point loads with exact locations not known along the joist or for incidental loads, any one, or both, of the following can be specified on the structural plan in addition to option 1 or 2 above:

a) "**Design for a (__) lb. concentrated load located at any one panel point along the joist**". This is referred to as an "Add-Load".

b) "**Design for additional bending stresses resulting from a (__) lb. concentrated load located at any location along (____) chord**". This is referred to as a "Bend-Check" and can be specified on **top** chord, **bottom** chord, or **both top and bottom** chords. This can be used when the concentrated load is already accounted for in the joist designation, uniform load, or specified Add-Load yet this specified amount of load shall be permitted to also be located at any location between panel points. The additional bending stresses as a result of this load are then designed for. A Bend-Check load shall not exceed (Add-Load + 400 lbs.) A Bend-Check load can be specified by itself without an Add-Load.

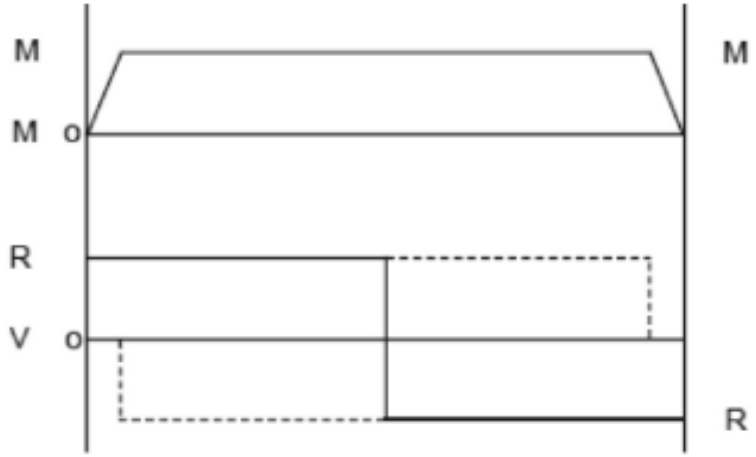
c) Both (a) and (b) above can be specified with equal concentrated loads for each; or simply denote "**Design joist for a (__) lb. concentrated load at any location along the (___) chord.**"

# KCS Joists

KCS Joist advantages:

1. Provides a versatile K-Series Joist that can be easily specified to support uniform and non-uniform loads plus concentrated loads applied at panel points.
2. Eliminate many repetitive load diagrams required on contract documents and allow some flexibility of load locations.

KCS Joist chords are designed for a flat positive moment envelope. The moment capacity is constant at all interior panels. All webs are designed for a vertical shear equal to the specified shear capacity and interior webs will be designed for 100% stress reversal.




**KCS JOIST**
**SHEAR AND MOMENT ENVELOPES**

Both LRFD and ASD KCS Joist load tables list the shear and moment capacity of each joist. The selection of a KCS Joist requires the specifying professional to calculate the maximum moment and shear imposed and select the appropriate KCS Joist.

# Evaluation of Existing Joist and/or Joist Girders

## Quick Check of a Joist

Length = 59’

Depth = 30”

5 “ chord width -

Means a 2 x 2 chord with a 1” space between the chords

What type of joist is it?

What is the bottom chord thickness?

Three measurements from 0.135” to 0.137”

# Evaluation of Existing Joist and/or Joist Girders

## Quick Check of a Joist

Vulcraft has an inventoried angle of 2x2x0.137

Area = 0.529 $in^2$

Centroid = 0.55 in

Effective Depth = deff= 30 in – 0.55 in – 0.56 in = 28.8”

Max tension force in BC = 0.6 x Fy x Area

0.6 x 50 ksi x 2 x 0.529 $in^2$ = 31.74 kip

Work length or reaction point of joist is 2” from the base length.

59’ – 2” – 2” = 58.67’

# Evaluation of Existing Joist and/or Joist Girders

## Quick Check of a Joist

Moment = $wl^2/8$ = max force x deff

w = (Fmax (kips) x deff (in) x 8 / $l^2\ ft^2$) x ft/12 in

= (31.74 kips x 28.8” x 8 / $58.67^2\ ft^2$) x ft/12 in

= 0.177 kips/ft = 177 lb/ft

# Evaluation of Existing Joist and/or Joist Girders

## Quick Check of a Joist

177 plf

**STANDARD LOAD TABLE FOR OPEN WEB STEEL JOISTS, K-SERIES**
**Based on a 50 ksi Maximum Yield Strength - Loads Shown In Pounds Per Linear Foot (plf)**

| Joist Designation | 28K6 | 28K7 | 28K8 | 28K9 | 28K10 | 28K12 | 30K7 | 30K8 | 30K9 | 30K10 | 30K11 | 30K12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth (In.) | 28 | 28 | 28 | 28 | 28 | 28 | 30 | 30 | 30 | 30 | 30 | 30 |
| Approx. Wt. (lbs./ft.) | 8.9 | 9.2 | 9.8 | 10.5 | 11.8 | 14.5 | 9.6 | 10.0 | 10.6 | 11 | 13.3 | 15.0 |
| Span (ft.) ↓ | | | | | | | | | | | | |
| 58 | | | | | | | 151<br>76 | 167<br>83 | 181<br>90 | 215<br>106 | 247<br>121 | 280<br>137 |
| 59 | | | | | | | 146<br>72 | 161<br>79 | 175<br>86 | 208<br>101 | 239<br>115 | 271<br>130 |
| 60 | | | | | | | 141<br>69 | 156<br>75 | 169<br>81 | 201<br>96 | 231<br>109 | 262<br>124 |

# Analysis Considerations

To analyze joist capacity

- Pinned connections are assumed for web members.
- Specifications for K-Series joists in the 2015 spec has changed.
  - Prior to 2015, in K-series bending between panel points from uniformly applied loads was neglected provided the top chord panel spacing did not exceed 24 inches.
  - In 2015 the bending from uniformly applied loads are considered, regardless of the panel spacing.
  - However, the K factor in the slenderness ratio is 0.75 in 2015 and 1.0 prior.
- Consequently, a decision needs to made regarding which spec is to be used for the evaluation of joists.

# Analysis Considerations (con't)

To analyze joist capacity

- A first-order analysis is used
- The SJI permits eccentricities to be neglected when
  - For K-Series, the "3/4 Rule" is followed - Spec 4.5 (c)
  - For all other joist series, when the eccentricity "…does not exceed the distance between the centroid and back of the chord"

# Web Eccentricity

For a web member composed of at least two shapes, the eccentricity on either side of the neutral axis of chord members, measured in the plane of the joist at the joint work point, shall be permitted to be neglected where the web intersection point does not exceed one and one-half times the distance between the neutral axis and the back of the chord in accordance with Figure 4.5-2 [shown here as Figure 1.11].

If these limits are exceeded, provision shall be made for the stresses due to eccentricity."

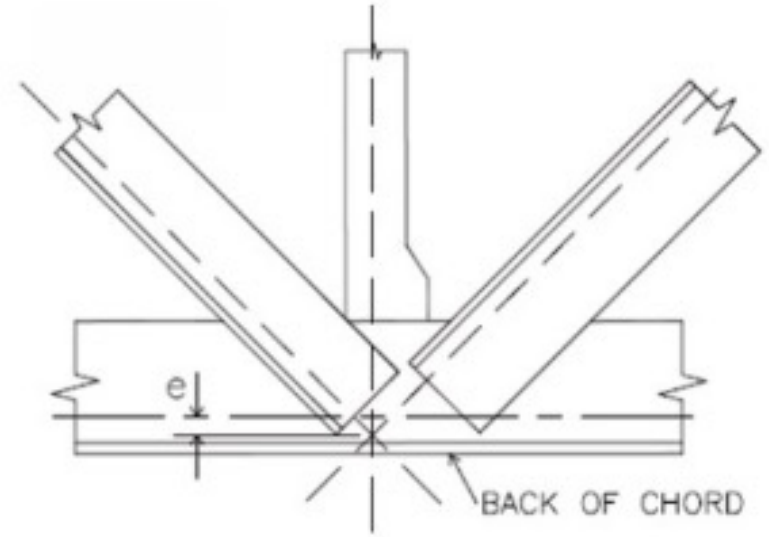



**Figure 1.11**
**Eccentricity for Web Member Composed of at Least Two Shapes**
(Standard Specification Fig. 4.5-2)

# OSHA Federal Regulation 29 CFR 1926.757 (a)(7)

No modification that affects the strength of a steel joist or steel joist girder shall be made without the approval of the project structural engineer of record.

# Determine if a Joist Requires Reinforcement

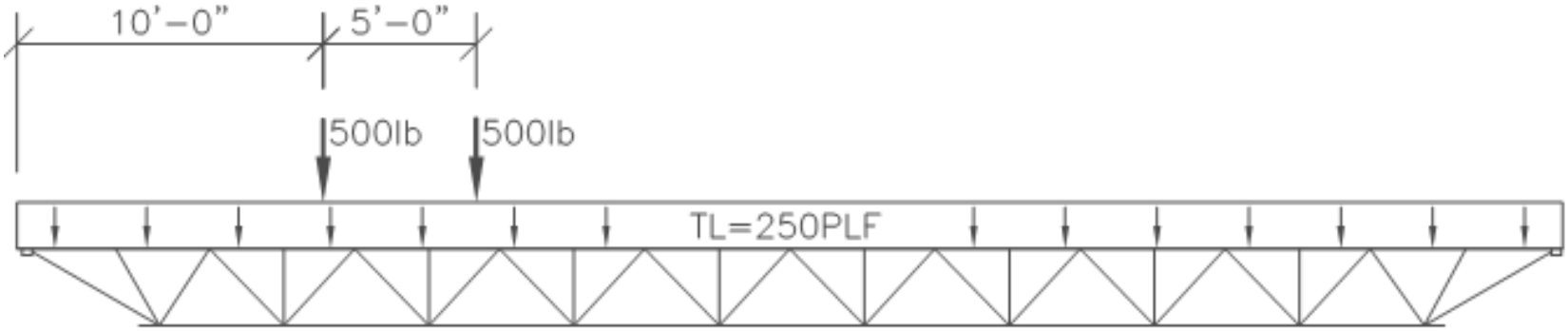
Scenario: K- series joist pre 2015 spec.

- A roof top unit is to be added to two 24K7 joists spanning 40 feet
- Unit adds two, 500 lb. point loads to each joist
  - Located 10 ft. and 15 ft. from one end
- It has been determined that the uniform load on the joist is 250 PLF

Determine if the joist must be reinforced

# Load Diagram

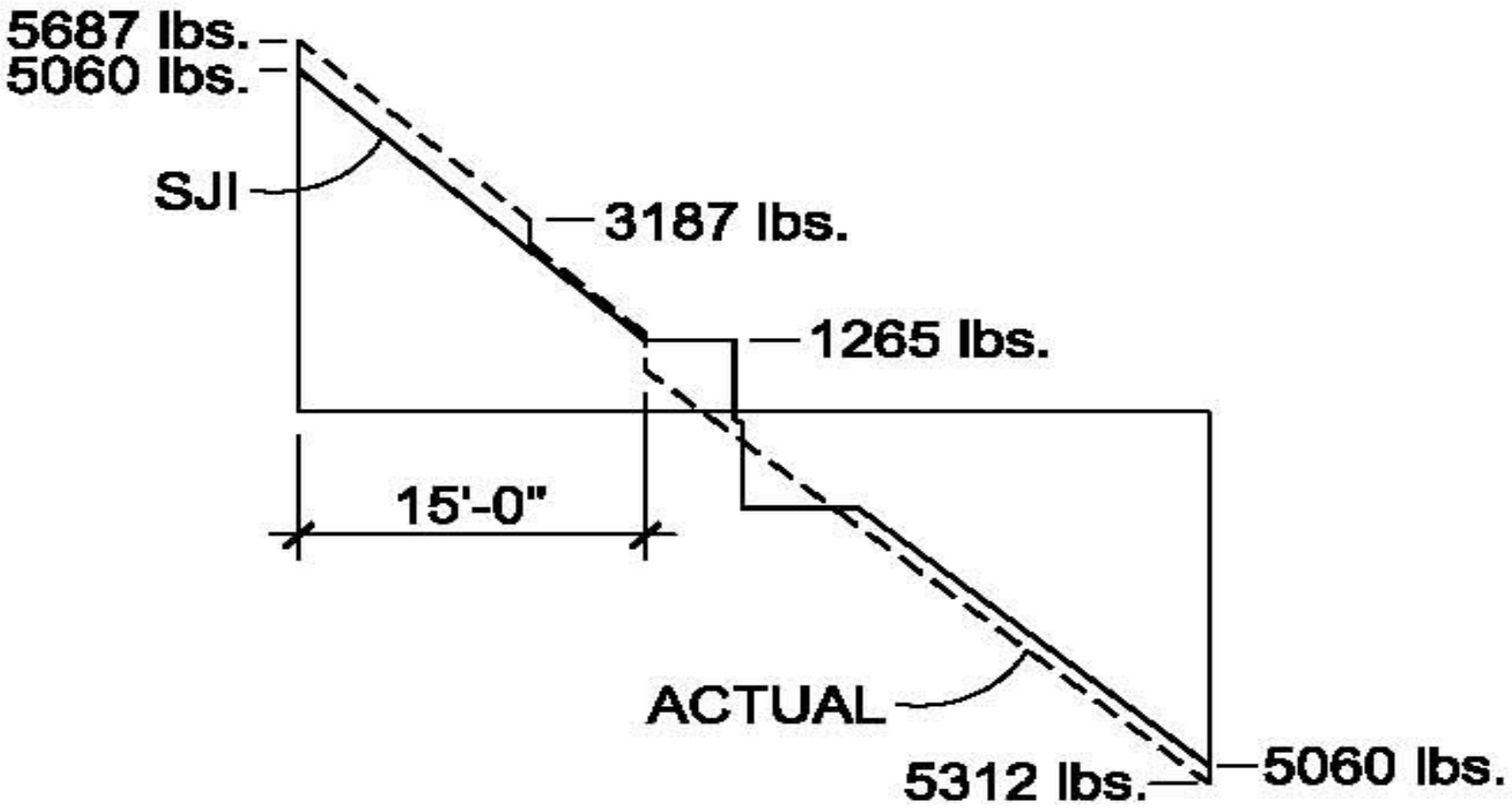

ORIGINAL DESIGN LOADS




ACTUAL LOADS

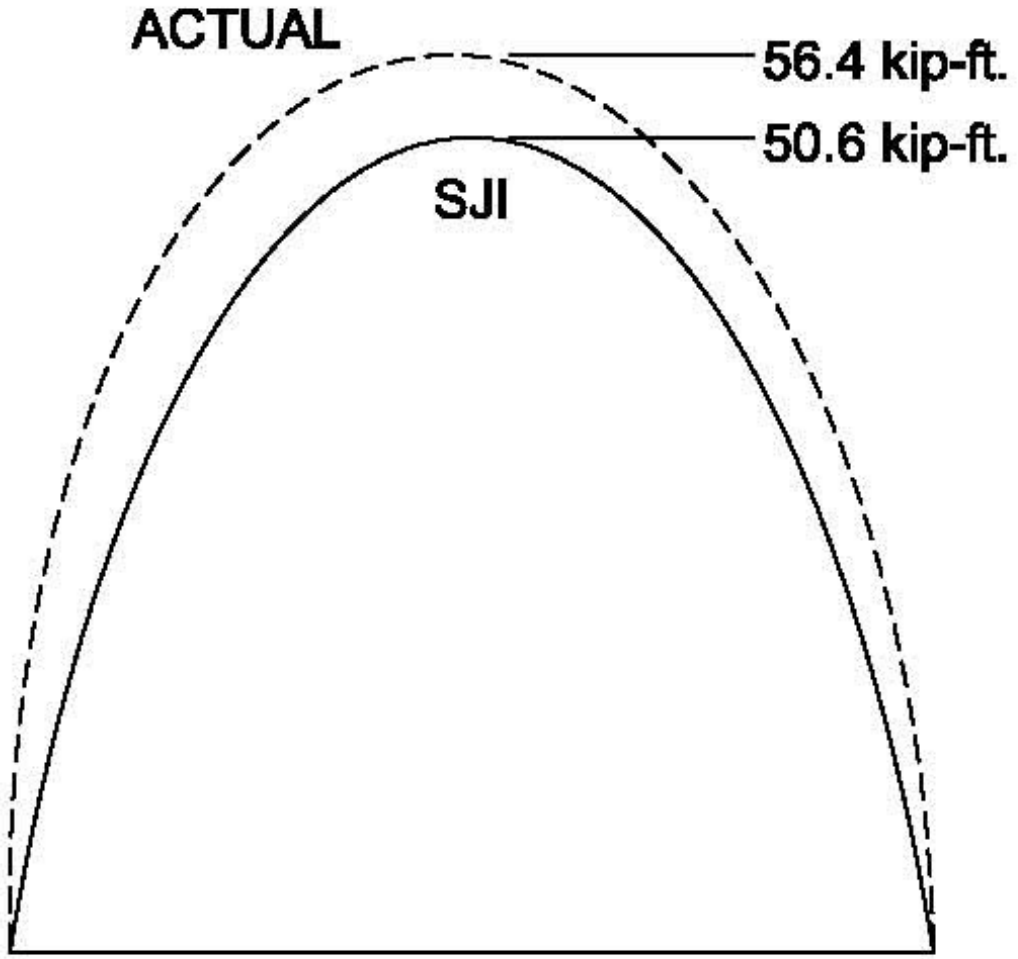
# Example 1

## Shear Envelope for 24K7 Joist

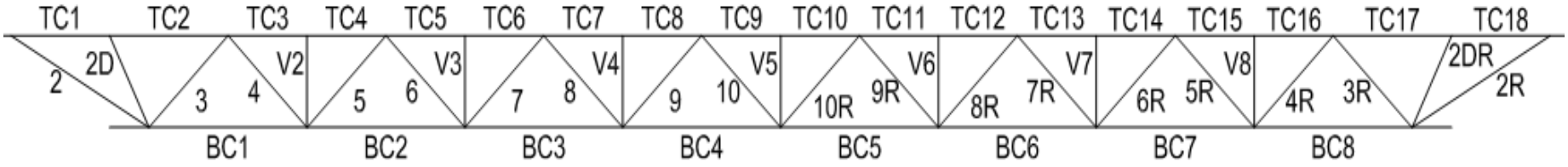


# Example 1

## Moment Diagram for 24K7 Joist



# Joist Diagram



# Existing Top Chord Review

Forces are compression

TC are continuous and segments 7 thru 12 have a larger axial force than the maximum in a 24K7.

| TC Segment Number | 24K7 Axial Design Force | Revised Loading Required Axial Force |
|---|---|---|
| 1 | 9937 | 11319 |
| 2 | 9477 | 10861 |
| 3 | 16924 | 19704 |
| 4 | 16924 | 19704 |
| 5 | 22207 | 25863 |
| 6 | 22207 | 25863 |
| 7 | 25374 | 29194 |
| 8 | 25374 | 29194 |
| 9 | 26429 | 29548 |
| 10 | 26429 | 29548 |
| 11 | 25374 | 27841 |
| 12 | 25374 | 27841 |
| 13 | 22207 | 24038 |
| 14 | 22207 | 24038 |
| 15 | 16924 | 18132 |
| 16 | 16924 | 18132 |
| 17 | 9477 | 10075 |
| 18 | 9937 | 10532 |

# Existing Top Chord Review

Forces are tension

BC are continuous and segments 3 thru 6 have a larger axial force than the maximum in a 24K7.

| BC Segment Number | 24K7 Design Axial Force | Revised Loading Required Axial Force |
|---|---|---|
| 1 | 13525 | 15606 |
| 2 | 19834 | 23322 |
| 3 | 24054 | 27948 |
| 4 | 26165 | 29600 |
| 5 | 26165 | 28955 |
| 6 | 24054 | 26202 |
| 7 | 19834 | 21352 |
| 8 | 13525 | 14426 |

# Existing Top Chord Review

- All the webs have higher (required) axial forces.
- Note the minimum shear used to determine the web axial force = 25% of the end reaction. (SJI spec. 4.4.2)
- Actual vs. Required weld lengths need to be checked.
- Design software can change the values.
- *** Note Load reversal

| Web Number | 24K7 Axial Force | Revised Loading Axial Force |
|---|---|---|
| 2 | + 11021 | + 12539 |
| 2D | - 1128 | - 1133 |
| 3 | - 5608 | - 6555 |
| 4 | + 4709 | + 5662 |
| V2 | - 600 | - 606 |
| 5 | - 4033 | - 4998 |
| 6 | + 3287 | + 3510 |
| V3 | - 635 | - 581 |
| 7 | - 2560 | - 2882 |
| 8 | + 1828 | + 2061 |
| V4 | - 638 | - 948 |
| 9 | -1828 | -2061 |
| 10 | + 1828 | -2061 *** |
| V5 | - 635 | - 665 |
| 10R | + 1828 | + 2061 |
| 9R | -1828 | -2061 |
| V6 | - 638 | - 649 |
| 8R | + 1828 | + 2265 |
| 7R | - 2560 | - 2990 |
| V7 | - 635 | - 645 |
| 6R | + 3287 | + 3711 |
| 5R | - 4033 | - 4450 |
| V8 | - 600 | - 610 |
| 4R | + 4709 | + 5120 |
| 3R | - 5608 | - 6011 |
| 2DR | - 1128 | - 1135 |
| 2R | + 11021 | + 11668 |

# Actual Member Load Carrying Capacity

- Evaluate the joist member to see what the actual member capacity is. There may be some extra capacity.
- Evaluate any conservative design assumptions to see if a more accurate condition occurs.
- Evaluate the length and placement of weld.
- Determine the risk of repair verses the in-place capacity.
- Use Engineering Judgment.

# Example 1a

Original Loads

- Assume 20 psf DL
- Assume 30 psf LL
- Assume 5’ joist spacing
- Total uniform load 250 plf

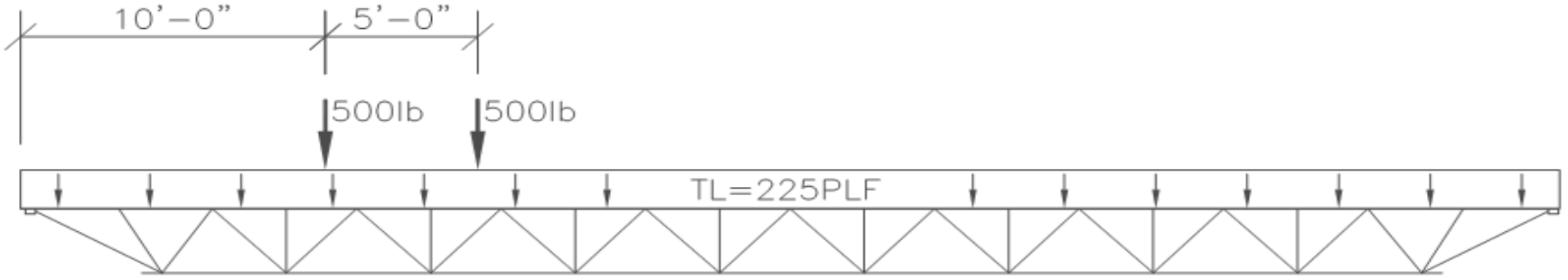
Revised Loads

- Assume 15 psf DL
- Assume 30 psf LL
- Assume 5’ joist spacing
- Total uniform load 225 plf

# Example 1a

Load Diagram


ORIGINAL DESIGN LOADS




ACTUAL LOADS

# Example 1a

## Top Chord Review

- Forces are compression
- Fewer segments have interaction ratios over 1.0 (and may be acceptable for the existing top chord capacity.)

| TC Segment Number | 24K7 Design Axial Force | Revised Loading Required Axial Force |
|---|---|---|
| 1 | 9937 | 10327 |
| 2 | 9477 | 9916 |
| 3 | 16924 | 18015 |
| 4 | 16924 | 18015 |
| 5 | 22207 | 23646 |
| 6 | 22207 | 23646 |
| 7 | 25374 | 26661 |
| 8 | 25374 | 26661 |
| 9 | 26429 | 26911 |
| 10 | 26429 | 26911 |
| 11 | 25374 | 25309 |
| 12 | 25374 | 25309 |
| 13 | 22207 | 21822 |
| 14 | 22207 | 21822 |
| 15 | 16924 | 16443 |
| 16 | 16924 | 16443 |
| 17 | 9477 | 9129 |
| 18 | 9937 | 9541 |

# Example 1a

## Bottom Chord Review

- Forces are tension
- Segments 4 thru 5 have a larger axial force than the maximum in a 24K7
- About a 3% greater force

| BC Segment Number | 24K7 Design Axial Force | Revised Loading Required Axial Force |
|---|---|---|
| 1 | 13525 | 14256 |
| 2 | 19834 | 21342 |
| 3 | 24054 | 25547 |
| 4 | 26165 | 26989 |
| 5 | 26165 | 26344 |
| 6 | 24054 | 23802 |
| 7 | 19834 | 19373 |
| 8 | 13525 | 13076 |

# Example 1.1a

Web Review

- Many webs still have higher axial forces
- The minimum web shear to calculate the web force = 25% of the end reaction
- Actual capacities need to be reviewed verses required forces
- Actual vs. Required weld length need to be verified.
- *** Still have load reversal

+ tension

- compression

| Web Number | 24K7 Design Axial Force | Revised Loading Required Axial Force |
|---|---|---|
| 2 | + 11021 | + 11441 |
| 2D | - 1128 | -1021 |
| 3 | - 5608 | -5998 |
| 4 | + 4709 | + 5194 |
| V2 | - 600 | -546 |
| 5 | - 4033 | -4598 |
| 6 | + 3287 | + 3184 |
| V3 | - 635 | -518 |
| 7 | - 2560 | -2627 |
| 8 | + 1828 | +1879 |
| V4 | - 638 | -885 |
| 9 | -1828 | -1879 |
| 10 | + 1828 | -1879 *** |
| V5 | - 635 | -602 |
| 10R | + 1828 | + 1879 |
| 9R | -1828 | -1879 |
| V6 | - 638 | -586 |
| 8R | + 1828 | + 2083 |
| 7R | - 2560 | -2736 |
| V7 | - 635 | -582 |
| 6R | + 3287 | + 3384 |
| 5R | - 4033 | -4049 |
| V8 | - 600 | -551 |
| 4R | + 4709 | + 4652 |
| 3R | - 5608 | -5454 |
| 2DR | - 1128 | -1021 |
| 2R | + 11021 | + 10570 |

# Example 1b

- An alternate approach would be to check the manufactured joist using the actual design dead and live loads in place of the load capacity from the SJI tables.
- From a review of the structural drawings the joist spacing is found to be 6 feet o.c. and the roof slope is ½:12.
- A check of the roof materials found that the actual roof dead load, including an allowance for the joist weight, is 15 psf.
- The required live load is 20 psf and is reducible.

# Example 1b

The roof live load can then be calculated based on IBC Equation 16-26

$$L_r = L_o R_1 R_2$$

where: $L_o = 20$ psf

$R_1 = 1.2 - 0.001A_t$ and $A_t = 6 \times 40 = 240$ sq. ft.

$= 1.2 - 0.001(240) = 0.96$

$R_2 = 1$ (for roof slope < 1:12)

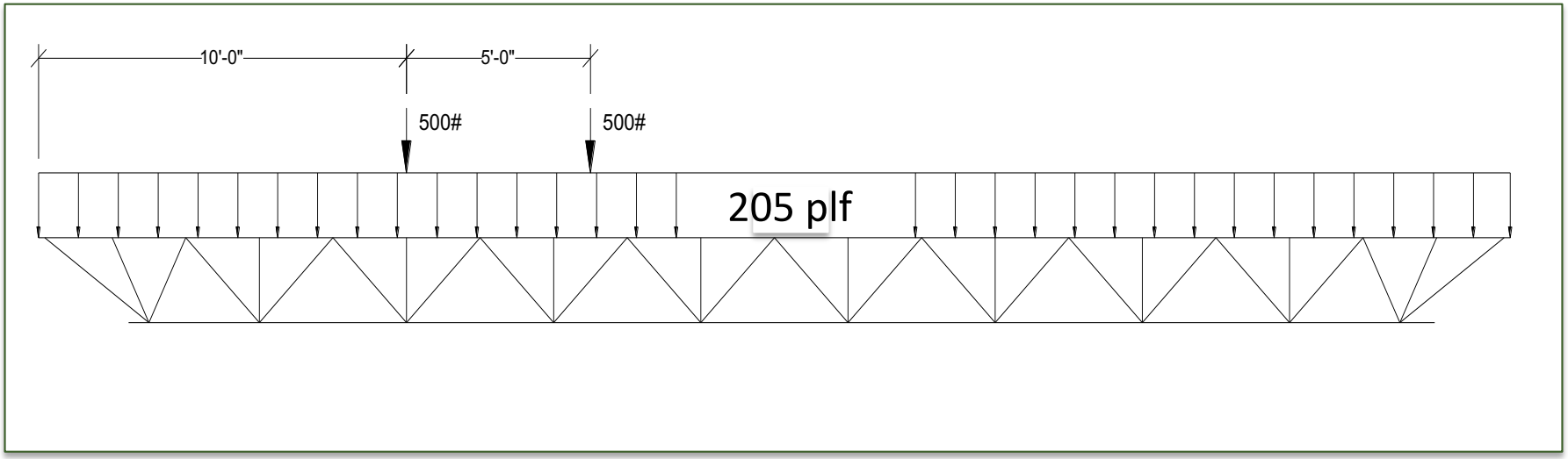
then: $L_o = 20(0.96)(1) = 19.2$ psf

and the joist $LL = 19.2(6) = 115.2$ plf

$DL = 15(6) = 90$ plf

# Example 1b

The manufactured joist can now be checked using the actual design loads DL = 90 plf & LL = 115 plf along with the two additional 500# loads.



# Example 1b

## Top Chord Review

- Forces are in Compression
- Comparison of Top Chord axial forces for 24K7 joist and for same joist with revised loads
- The top chord panels are acceptable

| TC Segment Number | 24K7 Design Axial Force | Revised Load Required Axial Force |
|---|---|---|
| 1 | 9937 | 9440 |
| 2 | 9477 | 9116 |
| 3 | 16924 | 16719 |
| 4 | 16924 | 16719 |
| 5 | 22207 | 21962 |
| 6 | 22207 | 21962 |
| 7 | 25374 | 25078 |
| 8 | 25374 | 25078 |
| 9 | 26429 | 24859 |
| 10 | 26429 | 24859 |
| 11 | 25374 | 23344 |
| 12 | 25374 | 23344 |
| 13 | 22207 | 20101 |
| 14 | 22207 | 20101 |
| 15 | 16924 | 15129 |
| 16 | 16924 | 15129 |
| 17 | 9477 | 8321 |
| 18 | 9937 | 8645 |

# Example 1b

Bottom Chord Review

- Forces are in tension
- Comparison of Bottom Chord axial forces for 24K7 joist and for same joist with revised loads
- All Bottom Chord panels are acceptable

| BC Segment Number | 24K7 Design Axial Force | Revised Loads Plus Conc. Loads Required Axial Force |
|---|---|---|
| 1 | 13525 | 13188 |
| 2 | 19834 | 19819 |
| 3 | 24054 | 23673 |
| 4 | 26165 | 24969 |
| 5 | 26165 | 24318 |
| 6 | 24054 | 21938 |
| 7 | 19834 | 17831 |
| 8 | 13525 | 11995 |

# Example 1b

## Web Review

- Webs 3, 4, 5, 8, & 8R have higher axial force.
- Note the minimum shear for calculating web axial force = 25% of the end reaction.
- *** Still have load reversal.
- Design software can change the values

| Web Number | 24K7 Axial Force | Actual Loads Axial Force |
|---|---|---|
| 2 | + 11021 | + 10458 |
| 2D | - 1128 | -745 |
| 3 | - 5608 | -5626 |
| 4 | + 4709 | +4880 |
| V2 | - 600 | -496 |
| 5 | - 4033 | -4283 |
| 6 | + 3287 | +2961 |
| V3 | - 635 | -522 |
| 7 | - 2560 | -2364 |
| 8 | + 1828 | +1941 |
| V4 | - 638 | -449 |
| 9 | -1828 | -1674 |
| 10 | + 1828 | -1674 *** |
| V5 | - 635 | -536 |
| 10R | + 1828 | +1674 |
| 9R | -1828 | -1674 |
| V6 | - 638 | -529 |
| 8R | + 1828 | +1942 |
| 7R | - 2560 | -2539 |
| V7 | - 635 | -513 |
| 6R | + 3287 | +3136 |
| 5R | - 4033 | -3733 |
| V8 | - 600 | -488 |
| 4R | + 4709 | +4330 |
| 3R | - 5608 | -5077 |
| 2DR | - 1128 | -741 |
| 2R | + 11021 | +9577 |

# Polling Question #2

Which of the following can reduce the need to evaluate and modify joists?

A. Add Loads

B. Bend-Check Loads

C. KCS Joists

D. All of the Above

# Chapter 2
# Methods of Supporting Additional Load

## Options before strengthening

- Capacity of joist needs to be determined
  - Can joist safely support new loads?
  - What are the actual loads?
  - What are the actual load cases?
  - Are stress ratios over 1.0 permitted?

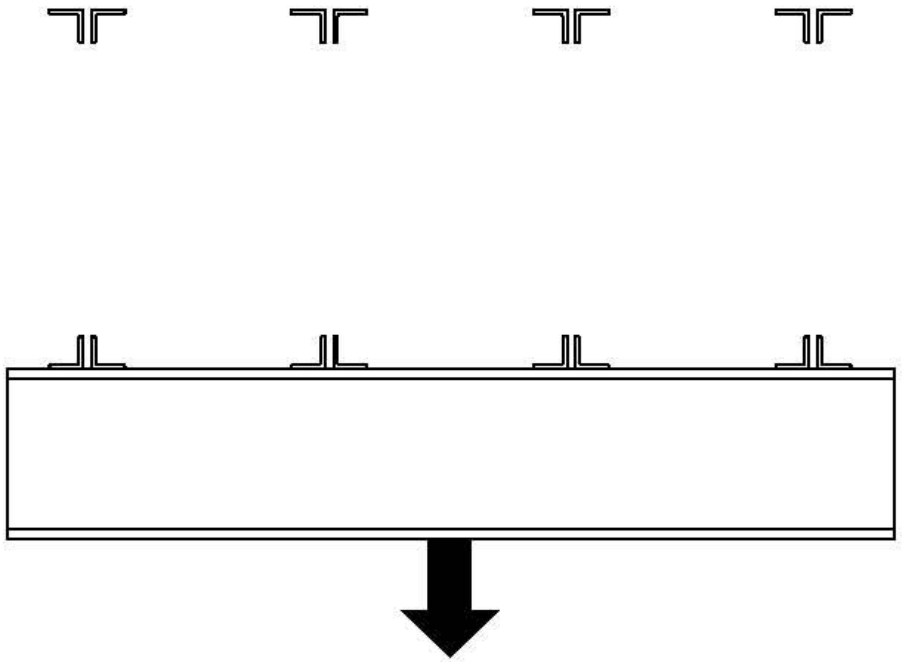
# Chapter 2
# Methods of Supporting Additional Load

## Options before strengthening

- Extensive reinforcement may not be practical
  - Option #1 - Load distribution
  - Option #2 - Add new joists or beams
  - Reinforce existing joists

# Load Distribution

- Member with Suitable Stiffness Required
- Place member under or through the joists
- Concentrated load distributed to several joists



# Load Distribution

- Relative stiffness is defined by beta

$$\beta = \sqrt[4]{\frac{(K/S)}{(4EI)}} \qquad \text{Eq. 2-1}$$

- Where,
  - K = stiffness of the joist, kips/in.
  - S = spacing of the joists, in.
  - E = modulus of elasticity for the beam, ksi
  - I = moment of inertia of the beam, in.4
  - β = characteristic parameter, 1/in.

# Load Distribution

$$\beta = \sqrt[4]{\frac{(K/S)}{(4EI)}}$$

- If S is less than π/4β
  - The spacing limit is not exceeded
  - S = spacing of the joists, in.
- If the length of the beam is less than 1/β
  - The beam may be considered rigid
  - Joist reactions may be determined by static equilibrium

# Example 2.1 Underhung Monorail Beam Using Load Distribution

This example will illustrate:

- How load distribution can eliminate the need for strengthening
- How to minimize the amount of strengthening by reducing the load to each joist
- How to design the distribution beam placed beneath the joist bottom chord

# Example 2.1 Underhung Monorail Beam Using Load Distribution

Given conditions:

- Hang new underhung monorail beam from the bottom chord of several joists
- Joists are 30K12 spanning 36’-0”
- Monorail adJoists are spaced 2’-6” o.c.
- ds a 1200 lb. concentrated load
  - Concentrated load located 10’-0” from joist end

# Example 2.1 Underhung Monorail Beam Using Load Distribution

## Determine the stiffness of the joists:

Determine approx. moment of inertia from

$$I_j = 26.767(W_{LL})(L^3)(10^{-6})$$

This is Eq. 2-2 in TD #12 and can also be found in the preamble of the SJI Load Tables

where,

WLL = nominal live load that will produce an approximate deflection of Span/360

(RED figure in the Load Table)

L = (Span – 0.33), ft.

# Example 2.1 Underhung Monorail Beam Using Load Distribution

## Determine the stiffness of the joists:

Determine approx. moment of inertia from

$$I_j = 26.767\left(W_{LL}\right)\left(L^3\right)\left(10^{-6}\right)$$

From the SJI K-Series Load Table, the live load deflection for a 30K12 joist with a 36’-0” span is:

WLL = 392 plf  Then,

$I_j$ =26.767(392)($35.65^3$)($10^{-6}$)=476 in4

# Example 2.1 Underhung Monorail Beam Using Load Distribution

Divide Ij by 1.15 to account for shear deflection:

$$I_{j,eff} = \frac{476}{1.15} = 414 in.^4$$

$$K = \frac{P}{\Delta}$$

From AISC Manual of Steel Construction, Table 3-23 for a simple beam- concentrated load at any point:

$$\Delta = \frac{Pa^2b^2}{3EIL}$$

$$K = \frac{P}{\Delta} = \frac{P}{\frac{Pa^2b^2}{3EI_{j,eff}L}} = \frac{3EI_{j,eff}L}{a^2b^2}$$

$$K = \frac{3(29000)(414)(35.67)(12)}{[(26)(12)]^2[(10)(12)]^2} = 11.0\ k/in.$$

# Example 2.1 Underhung Monorail Beam Using Load Distribution

Determine the beam size necessary to distribute the load to three (3) joists:

Try W16 x 26  Ix = 301 in.4

$$\beta = \sqrt[4]{\frac{(K/S)}{(4EI)}} = \sqrt[4]{\frac{11.0/30}{(4)(29000)(301)}} = 0.0101\ in.^{-1}$$

$$S < \frac{\pi}{4\beta} = 77.6\ in.$$

Check if spacing,

S = 30 in. < 77.6 in.  Therefore, OK

# Example 2.1 Underhung Monorail Beam Using Load Distribution

Determine the beam size necessary to distribute the load to three joists:

For W16 x 26 $\beta = 0.0101$ in.-1

$$L < \frac{1}{\beta} in.$$

Check the length of monorail support beam

Beam Length L= 5.0 ft. = 60 in.

$1/\beta = 1/0.0101 = 98.8$ in.

60 in. < 98.8 in. Therefore, OK

# Example 2.1 Underhung Monorail Beam Using Load Distribution

- Solve for the reaction at each joist:
- Since the beam can be considered rigid,
  - 1200 lbs. can be uniformly distributed to each joist support
  - 1200 lbs. / 3 = 400 lbs. additional load
- Note: Don't forget to include the beam self-weight. It might not be insignificant.

# Reinforcing / Replacing / Adding

Considerations:

- Cost
- Time
  - Engineering and Labor for Field Reinf.
  - Manufacturing and Installing a New Joist,
- Difficulty of repair - Interferences, Access
- Effectiveness of Reinforcing
- Skill of workman

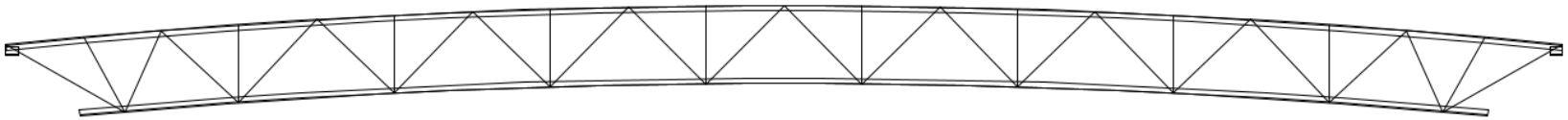
# Reinforcing / Replacing / Adding

Considerations:

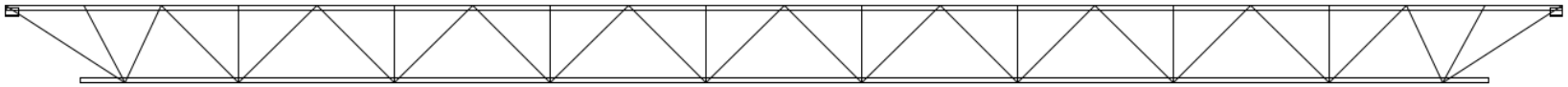
- Existing interferences
  - Piping, electrical conduits, other interferences
  - Removing or relocating could be at a greater expense than reinforcement
- Camber
  - May need to reduce camber in new joists
  - Joists can be ordered with shallower seat depths and then shimmed in the field
  - The joist can be supplied with a splice so two individual pieces can be installed and bolted at the center
- Lateral Stability of the joist top chord
  - Shoot pins through the chord, decking, and slab
  - Rely on bridging to provide lateral support

# Reinforcing / Replacing / Adding

Camber – Joists manufacturers rigging tables are set up for SJI standard camber. If replacing or adding a joist, specify zero or no camber.



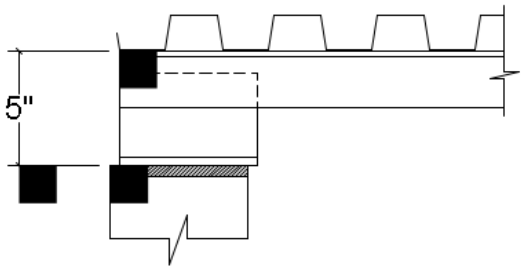
MANUF'D JOIST W/ STD. CAMBER
PRIOR TO INSTALLATION



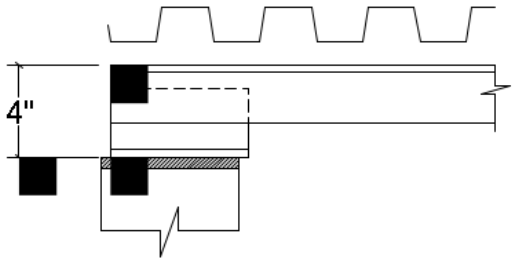
JOIST AFTER INSTALLATION
WITH DEAD LOADS APPLIED

# Reinforcing / Replacing / Adding

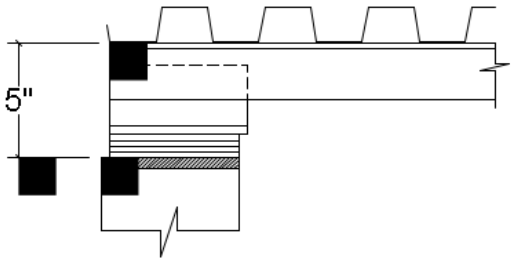
Bearing Seat Depth – Specify a shallower seat depth and then shim to raise top chord to deck.




INSTALLED BEARING SEAT FOR EXISTING JOIST



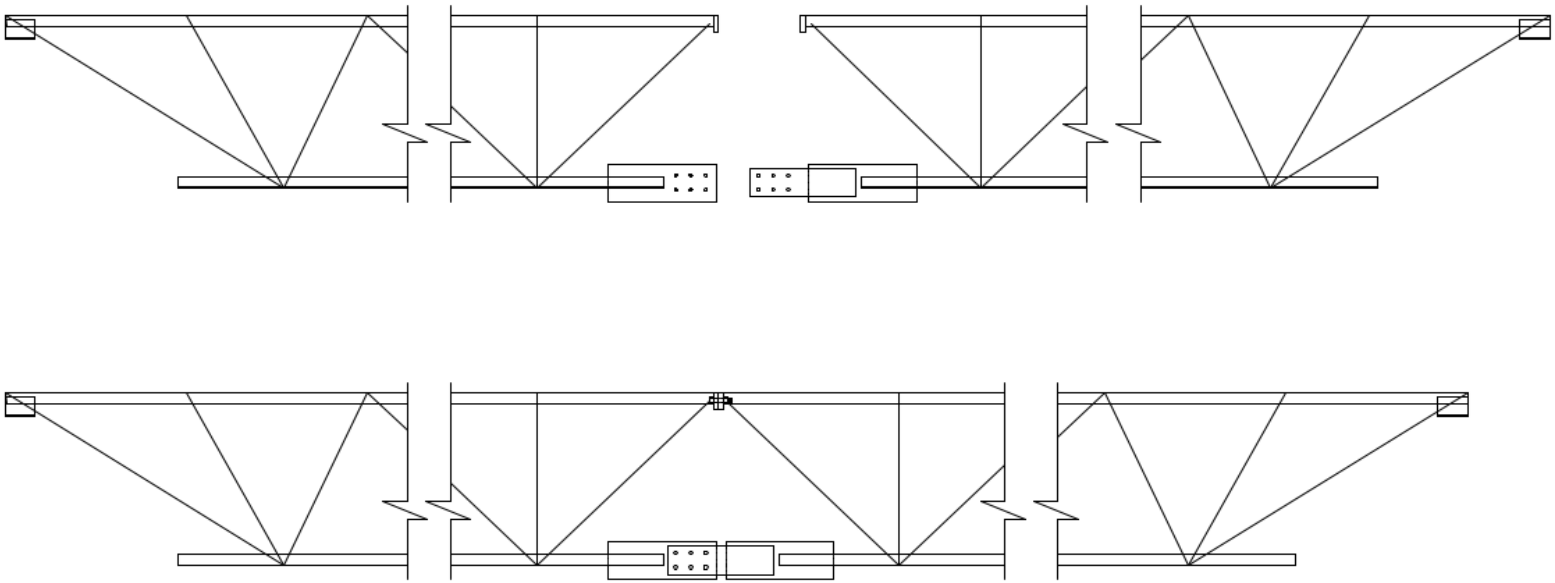

NEW JOIST W/ SHALLOWER BEARING SEAT PRIOR




NEW JOIST W/SHAOOWER BEARING SEAT AND SHIMMS

# Reinforcing / Replacing / Adding

SPLICE – Using a joist w/ a field bolted splice allows each half of the joist set in place and then mated together.



JOIST W/ BOLTED SPLICE

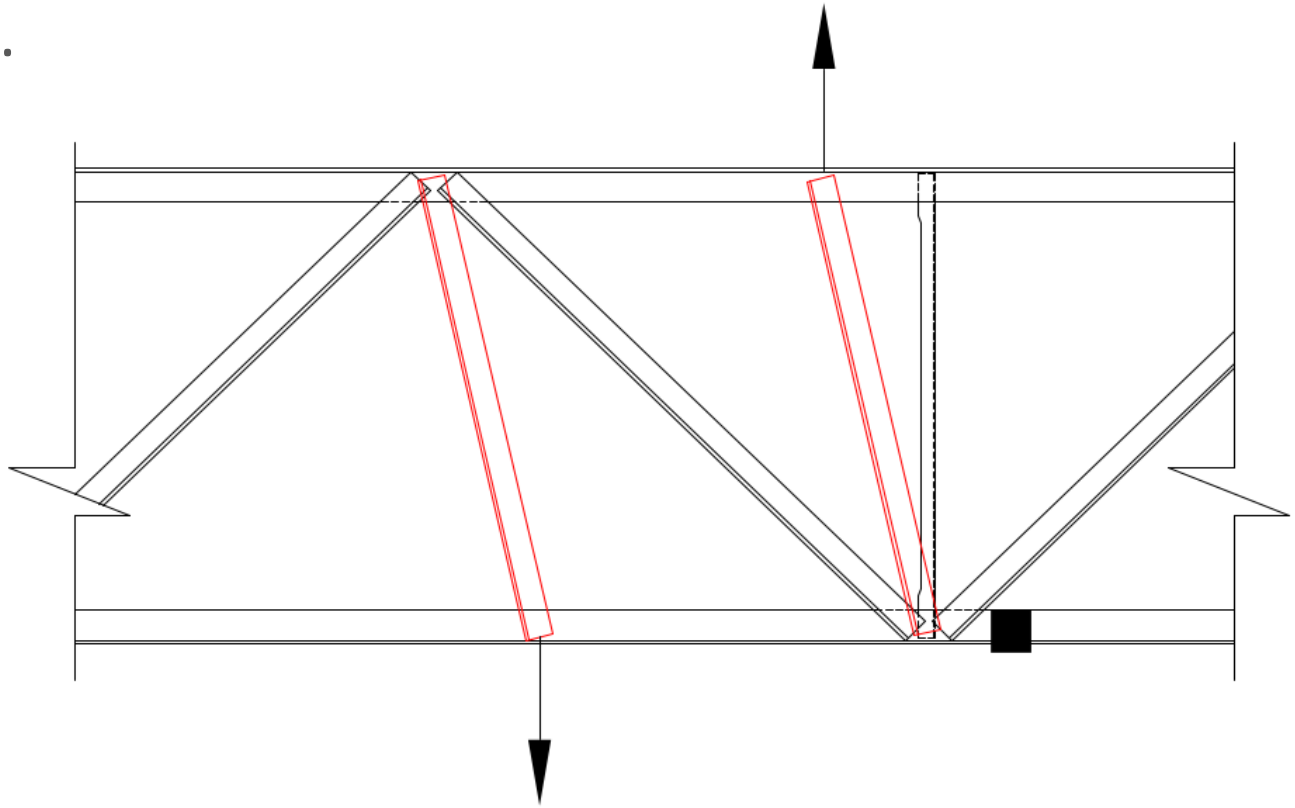
# Reinforcing Existing Joists

The following will impact reinforcement of both chord and web members:

- Rod web joists
  - New reinforcing webs can be easily added on the outside of the chords.
  - Chords are typically thin angles.
- Crimped angle web joists
  - New reinforcing webs can be easily added on the outside of the chords.
  - If chords and webs need to be reinforced there could be interferences which affect how the reinforcement is done.

# Reinforcing Existing Joists

For larger LH-Series and Joist Girders - Double angle diagonal webs may intersect at a bottom chord panel point there will not be room to add and weld a reinforcing web at that panel point to pick up a load. The chord will have to be checked for local bending.



# Reinforcing Existing Joists

The following will impact reinforcement of both chord and web members:

- Chord and web yield strength
  - Since about 1980, 50 ksi steel has been used for chord and webs.
  - Older joists may have been manufactured using 36 ksi steel and test coupons may be required to determine the Yield Strength of the joist members.

# Reinforcing Existing Joists

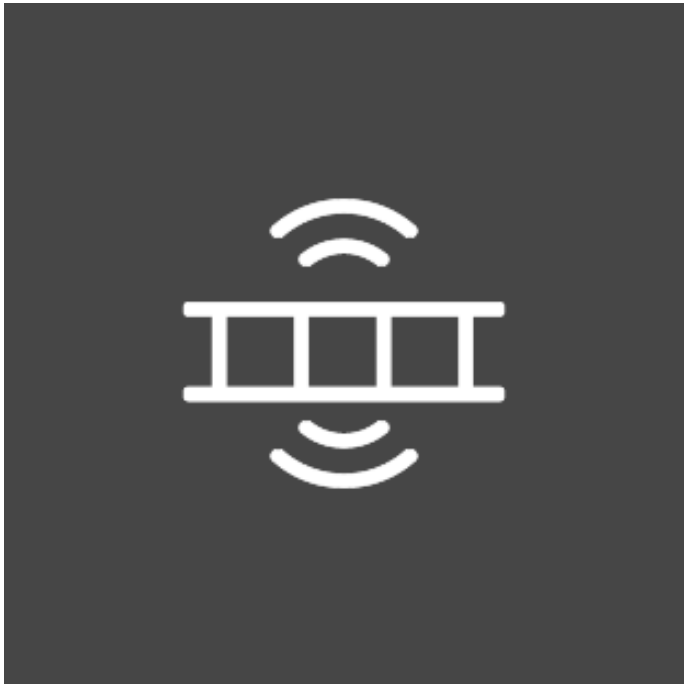
Other considerations:

- Additional weld may be required even though web member size is sufficient for new loads
- Accessibility to reinforce either chord or webs
  - May only be able to reach one side of the joist
- Eccentricities

# SJI Design Tools

Free downloads:

- Steel Joist Uplift Analysis Tool
- Joist Girder Analysis Tool
- Joist and Joist Girder Reinforcement Tool
- Historical Load Tables
- Roof Bay Analysis Tool w/ Ponding Analysis
- Floor Bay Analysis Tool w/ Vibration Analysis
- Joist Girder Moment Connection Design Tools
- Virtual Joists
- Virtual Joist Girders
- Floor Vibration



# SJI Publications

**Technical Digests**

- #3 Structural Design of Steel Joist Roofs to Resist Ponding Loads
- #5 Vibration of Steel Joist – Concrete Floors
- #6 Design of Steel Joist Roofs to Resist Uplift Loads
- #7 Special Profile Steel Joists and Joist Girders
- #8 Welding of Open Web Steel Joists and Joist Girders
- #9 Handling and Erection of Steel Joists and Joist Girders
- #10 Design of Fire-Resistive Assemblies with Steel Joists
- #11 Design of Lateral Load Resisting Frames Using Steel Joists and Joist Girders
- #12 Evaluation and Modification of Open Web Steel Joists and Joist Girders
- #13 Specification and Design of Composite Steel Joists

**Catalogs**

- 45th Edition Standard Specifications Load Tables and Weight Tables for Steel Joists and Joist Girders - *Free download*
- Second Edition CJ-Series Composite Steel Joists – *Free download*
- 90 Years of Open Web Steel Joist Construction

# SJI Webinars

- Earn PDHs with the 2024 webinars
- SJI's first Spanish webinar (free) is November 6, 2024
  - Joist de acero y Joist Girders ampliados y más fáciles de usar
- Part 2 live webinar is November 20, 2024
  - Evaluation and Modification of Steel Joists and Joist Girders – part 2
- Webinars On Demand
  - Watch 60+ pre-recorded webinars. Order the online accompanying quiz to earn your PDHs.

# Polling Question #3

When doing a joist repair, what is generally the most expensive?

A. Material

B. Labor

# Q&A SESSION

# THANK YOU



*Presented by:*

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